SECTION 500. STRUCTURES

BRIDGES

SECTION 501. REMOVAL OF EXISTING STRUCTURES

501.01 Description. This work shall consist of the removal and satisfactory disposal of existing traffic and drainage structures or portions thereof, as specified.

CONSTRUCTION REQUIREMENTS

501.02 Complete Removal of Structures. Materials that are to be salvaged under the contract and which the Engineer deems fit for reuse shall be carefully removed in transportable sections and stockpiled near the site at a location designated by the Engineer. If the material for reuse is unfit, through no fault of the Contractor, the material shall be disposed of according to Article 202.03. When the Contractor damages or destroys such material, the Contractor shall repair or replace it at his/her own expense and in a manner satisfactory to the Engineer.

When specified that the superstructure is to be salvaged for reerection, all members and loose parts shall be properly matchmarked, all machined steel surfaces treated with an approved anti-rust compound, and all loose parts wired to adjacent members, or packed in marked boxes.

Materials that are not to be salvaged and stockpiled shall become the property of the Contractor and shall be removed and disposed of according to the requirements of Article 202.03.

Existing structures shall be removed to at least 300 mm (1 ft) below the proposed elevation of subgrade or ground surface, within the area of construction and within the limits of the right of way. All portions of existing structures below this elevation that interfere in any way with the new construction, shall be removed.

The location, size, and type of existing culverts to be removed shall be as shown on the plans or as directed by the Engineer. When existing culverts are designated to be salvaged, the removal operation shall be performed in a manner that will not cause damage to the existing culvert.

Existing concrete slope wall shall be removed at the locations shown on the plans and as directed by the Engineer so all loose material shall be removed and disposed of as specified. It shall be the responsibility of the Contractor to determine the thickness of the slope wall to be removed and the extent to which it is reinforced. No additional compensation will be allowed because of variations from the assumed thickness or from the thickness shown on the plans, or for variations in the amount of reinforcement. When only partial removal of existing concrete slope wall is to be performed, the removal shall be performed according to Article 501.03.

501.03 Partial Removal of Structures. Where portions of existing structures are to remain in service, portions to be removed shall be removed in such a manner as to leave the structure undamaged and in proper condition for the use contemplated. Any damage to the portions remaining in service shall be repaired by the Contractor at his/her own expense. Old concrete or masonry shall be carefully removed to the lines designated unless otherwise directed by the Engineer. Prior to concrete removal, a saw cut approximately 20 mm (3/4 in.) deep shall be made along all boundaries of full-depth removal areas adjacent to areas to remain in place. For slabs the boundaries of full-depth removal shall be saw cut on the top surfaces. The concrete shall then be removed with jackhammers not heavier than the nominal 20 kg (45 lb) class and suitable hand tools. Final removal at the designated lines of full-depth removal shall be accomplished by 7 kg (15 lb) chipping hammers or hand tools, with particular care being exercised at the bottom of the slab to avoid breakage beyond the designated removal line. The surfaces presented as a result of this removal shall be reasonably true and even, with sharp straight corners that will permit a neat and workmanlike joint with the new construction or be satisfactory for the purpose intended. Where existing bars are to extend from the remaining portions of existing structures into new construction, the concrete shall be removed so as to leave the projecting bars clean and undamaged. All newly exposed concrete and exposed reinforcement bars to be incorporated into new concrete shall be blast-cleaned. Where projecting bars are not to extend into the new construction, they shall be cut off flush with the surface to which the old concrete has been removed. Upon removal of the falsework, the bottom surfaces of new concrete, adjacent to remaining portions of existing concrete, shall be inspected with hammer sounding to detect loose and delaminated areas which may constitute a hazard to underlying roadways and railroads. Those areas shall be removed as directed by the Engineer. All removed areas 25 mm (1 in.) or deeper shall be repaired with an approved method. This removal and repair shall be completed to the satisfaction of the Engineer.

At the Contractor's option, hydrodemolition equipment meeting the requirements of Article 1101.11 will be permitted for partial removal of structures in lieu of the equipment specified above. Operation of the hydrodemolition equipment shall be performed and supervised by qualified personnel certified by the equipment manufacturer. Evidence of certification shall be presented to the Engineer. When partial-depth removal is required, the equipment shall be calibrated and set to remove sound concrete to the required depth. If sound concrete is being removed below the required depth, the Engineer will require the equipment to be recalibrated and reset. The Contractor shall be responsible for disposing of the runoff water generated by the hydrodemolition operation. Runoff water shall not be allowed to constitute a hazard on adjacent or underlying roadways or railroads, or to erode existing slopes.

When full deck removal is specified, tools used for breaking or removing the concrete deck which is attached to or supported by portions of the structure that are to remain in service shall be limited to jackhammers or hydraulic hammers having a maximum rated striking energy of 1600 J (1200 ft lb). Drop hammers or other free falling type equipment will not be permitted. The Contractor shall exercise care so as not to notch or gouge the top flanges with jackhammers or other tools. When transverse saw cutting of the deck is utilized for full deck removal, the Contractor shall mark on top of the concrete deck the locations of the top flanges of all the steel beams or girders, prior to any removal of the bridge deck. Saw cutting directly over the top of the beam or girder flanges will not be permitted. Any damage to the

existing steel shall be repaired by the Contractor at his/her own expense. Repairs shall be made as directed by the Engineer.

Where existing box culverts are to be extended, the Contractor shall remove such portions of the existing headwalls, wingwalls and barrel at the ends to be extended as indicated on the plans. If no provision is made on the plans or elsewhere for removing the old headwalls and wingwalls at the ends to be extended, they shall be removed, either down to the top of the old barrel or to 300 mm (1 ft) below the proposed elevation of the subgrade or ground line above the old headwalls and wingwalls. When the old headwalls and wingwalls are to be removed below the top of the old barrel, the reinforcing steel from the old portion of the culvert shall be bent into the new construction.

When the headwall is to be removed, it shall be disposed of in a manner approved by the Engineer and according to Article 202.03. The removal shall be performed so the existing pipe culvert to remain in place is not damaged. Any damage to the existing culvert shall be repaired or replaced by the Contractor at his/her expense.

At locations designated by the Engineer, all earth and debris shall be removed from the invert of the portions of existing culverts which are to remain in place.

501.04 Method of Measurement. When paid for as a separate item, removal of existing structures, removal of existing superstructures, removal of existing concrete deck, and removal of existing concrete headwall for pipe culverts will be measured for payment in units of each at the location designated on the plans.

Slope wall removal will be measured for payment in place and the area computed in square meters (square yards) of concrete slope wall to be removed.

Removal of existing culverts will be measured in place in meters (feet) of existing culvert to be removed. The measurement shall be along the flowline of the culvert.

When specified on the plans, removal of existing bridge rail will be measured in place in meters (feet) out to out and along the top longitudinal rail element. Posts will not be measured for payment.

When paid for as a separate item, the removal of concrete or masonry for partial removal of structures will be measured for payment and the volume computed in cubic meters (cubic yards) of concrete or masonry to be removed.

Any excavation necessary to perform the removal of existing structures shall be considered included in that item of work and will not be measured for payment.

Removal and disposal of all rails, posts, and connecting hardware associated with the bridge rail will not be measured for payment.

501.05 Basis of Payment. When the contract contains a separate item for removal, it will be paid for at the unit price per each for REMOVAL OF EXISTING STRUCTURES, REMOVAL OF EXISTING SUPERSTRUCTURES, or REMOVAL OF EXISTING CONCRETE DECK at the location designated on the plans.

When provided in the contract, the removal of portions of concrete or masonry structures in the manner specified under Article 501.03, and the disposal of the materials, will be paid for at the contract unit price per cubic meter (cubic yard) for CONCRETE REMOVAL or for MASONRY REMOVAL.

Disposal of materials specified for salvage but deemed unfit for further use through no fault of the Contractor will be paid for according to Article 109.04. If existing structures or existing concrete or masonry are specified to be removed and no separate items or unit prices for such removal are provided in the contract, payment for this work will be considered as included in the contract unit prices for other items of work involved, except as provided for Rock Excavation for Structures in Section 502.

Removal of existing pipe culvert concrete headwalls will be paid for at the contract unit price each for CONCRETE HEADWALL REMOVAL.

Removal of existing pipe culverts will be paid for at the contract unit price per meter (foot) for PIPE CULVERT REMOVAL.

Removal of existing slope wall will be paid for at the contract unit price per square meter (square yard) for SLOPE WALL REMOVAL, which price shall include any headwalls or aprons attached to the culvert.

Removal of existing bridge rail will be paid for at the contract unit price per meter (foot) for BRIDGE RAIL REMOVAL.

When the Engineer directs that earth and debris be removed from culvert inverts, such removal will be paid for according to Article 109.04.

The cost of the removal and disposal of all other existing structures which are visible above ground and the Contractor could be reasonably expected to have knowledge of them, shall be considered as included in the contract unit price for the major item of work in the contract, and no additional compensation will be allowed. In the event existing structures or portions of existing structures are encountered which cannot be removed by normal excavation procedures and are not shown on the plans or are not evident in the field and are required to be removed, the cost of such removal will be paid for according to Article 109.04.

SECTION 502. EXCAVATION FOR STRUCTURES

502.01 Description. This work shall consist of the excavation required for the construction of all structures including all bailing, draining, pumping, sheeting; the construction of cofferdams, or temporary cribs if found necessary, and their subsequent removal; the disposal of all material obtained from such excavation; and backfilling to the level of the ground surface as it existed before any excavation was made by the Contractor.

CONSTRUCTION REQUIREMENTS

502.02 Clearing, Tree Removal and Protection of Existing Plant Material. Prior to starting excavation operations in any area, all clearing, tree removal and protection of existing plant material in that area shall be performed as specified in Section 201.

502.03 General. Excavation for structures shall include all materials encountered, regardless of their nature.

Structure Excavation shall include all excavation except rock excavation or excavation within a cofferdam.

Cofferdam Excavation, when specified, shall include all excavation within the limits of a cofferdam, except rock excavation.

Rock Excavation for Structures shall consist of the excavation of boulders 0.5 cu m (1/2 cu yd) in volume or greater and all rock in ledges, bedded deposits and conglomerate deposits exhibiting the physical characteristics and difficulty of rock removal as determined by the Engineer. After the Engineer has made the determination that the material qualifies as rock excavation, the Contractor may use any method he/she chooses including ripping to remove the rock excavation. Rock Excavation for Structures shall also include existing concrete, masonry, timber grillages, foundation piles and similar materials, which are not exposed to view and are not shown on the plans and for which payment is not otherwise provided.

502.04 Sequence of Operations. The elevations of the bottoms of footings, as shown on the plans, shall be considered as approximate and the Engineer may order such changes in dimensions or elevations of footings as may be necessary to secure a satisfactory foundation. Where foundation piles are used, the excavation of each footing, as shown on the plans, shall be completed before the piles are driven. After the piles are driven, all loose and displaced material shall be removed to the bottom of the footing elevation.

502.05 Excavation in Rock. Where the footing excavation is in rock, the rock shall be excavated to the plan dimensions of the footing or foundation seal. No rock shall project inside of such dimension more than 50 mm (2 in.). Other rock excavation shall be as necessary for the construction of the structure, subject to the limitations for measurement for payment specified in Article 502.14. All cracks, voids, seams or other irregularities in the excavation shall be cleaned and filled with concrete

502.06 Cofferdams. Cofferdams shall consist of watertight enclosures surrounding excavations. When cofferdams are not specified in the contract documents and conditions are encountered where the excavation for the structure cannot be kept free of water for prosecuting the work by pumping and/or diverting water by the use of sheeting or dikes, the Contractor, with the written permission of the Engineer, will be permitted to construct a cofferdam.

The cofferdams shall be designed, constructed, and removed with the Engineer's approval. Cofferdams shall consist of engineered structural components consisting of

timber, standard steel sheet pile sections, structural steel sections, cylindrical metal shells, or a combination of the above. Earthen embankments or dikes will not be classified as cofferdams.

The Contractor shall submit drawings and design calculations showing the proposed design, method of construction, removal, as well as other details left open to choice or not fully detailed on the plans. The design and method of construction shall provide, within the measurement limits specified in Article 502.14, necessary clearance for forms, inspection of exterior of the forms, pumping, protection of fresh concrete from rising water, and protection of the footing from erosion. No component of the cofferdam shall extend into the substructure concrete without written permission of the Engineer. These drawings shall be submitted to the Engineer and approved prior to the start of construction. This approval shall not relieve the Contractor of responsibility of the cofferdam.

(a) Foundation Seal. Foundation seal coats shall be constructed according to Article 503.15. When a cofferdam and seal coat are added to the contract by written permission of the Engineer, the design of the seal coat, including design calculations, shall be included in the overall design of the cofferdam when submitted to the Engineer for review and approval. When the excavation within the cofferdam has been completed and piles have been driven, the elevation of the bottom of the cofferdam shall be determined by soundings. The equipment and methods used to conduct the soundings shall meet the approval of the Engineer. Any material higher than the plan elevation of the bottom of seal coat shall be removed.

(b) Removal. Removal shall be according to the previously approved procedure. Unless otherwise approved in writing by the Engineer, all components of the cofferdam shall be removed.

502.07 Excavation Other Than Rock. When the structure excavation occurs in material other than rock, the limits of the excavation shall not exceed the dimensions specified in Article 502.14. These limits may be exceeded only with the permission of the Engineer and subject to the limitations for measurement for payment specified in Article 502.14. The depth of the excavation shall be carried to the plan bottom of the footing elevation. If the material encountered at the plan bottom of the footing elevation is soft, muddy, or otherwise unsuitable, the material shall be removed to an additional depth as directed by the Engineer and replaced with crushed stone, gravel or other material approved by the Engineer.

502.08 Pumping. Pumping from the interior of a foundation enclosure shall be done in a manner approved by the Engineer. Pumping will not be allowed during placement of the concrete or for a period of 24 hours after completion of the placement, unless the pumping is accomplished from a watertight sump separated from the concrete being placed. Pumping to dewater a sealed cofferdam shall not begin until the seal coat has attained the design strength.

502.09 Inspection. After each excavation is completed, the Contractor shall notify the Engineer. No concrete shall be placed until after the Engineer has approved the depth of the excavation and the character and condition of the foundation material. When ordered in writing by the Engineer, the bottom of the excavated space within any cofferdam in which a foundation seal is to be constructed shall be inspected by a qualified diver, employed by the Contractor, and paid for according to Article 109.04. In such cases, the Department will not pay for any services performed by the diver other than the inspection.

502.10 Backfilling. Backfilling shall consist of placing and compacting the necessary fill within the space excavated for a structure below the ground surface as it existed before any excavation was made by the Contractor. Fill required above the ground surface as it existed prior to excavation for the structure is considered as embankment. Bracing, forms and rubbish shall be removed from the excavation before the backfill is placed. Unless sheeting is to remain in place, it shall be removed at such time as directed by the Engineer to best prevent loosening unexcavated material and facilitate placing and compacting the backfill. Sloping sides of the excavated space to cause objectionable wedging action of the backfill against the structure, shall be stepped or serrated to prevent such action.

Where the original ground surface is higher than the proposed elevation of roadway surface, stream banks or channels, the backfill shall be constructed up to the elevation designated as the proposed ground surface.

Backfill which is to serve as a roadbed, or upon which embankment is to be placed, shall be constructed by materials satisfactory to the Engineer. No sod, frozen material or any material which, by decay or otherwise, might cause settlement, shall be placed or allowed to remain in the backfill at such locations. Whenever the material obtained from the excavation is suitable, it shall be used in constructing the backfill. Excavated material that is unsuitable for backfill only because it contains too much moisture shall be allowed to dry before being used as backfill. Excavated material unsuitable for backfill shall be disposed of as specified in Article 502.11. If the amount of suitable excavated material is insufficient, suitable material shall be obtained and used for making or completing the backfill.

In placing backfill or embankment, the material shall be placed simultaneously insofar as possible to approximately the same elevation on both sides of a wall, pier or column. If conditions require placing backfill or embankment appreciably higher on one side of a wall, pier or column than on the opposite side, the additional material on the higher side shall not be placed until test specimens show that the concrete has attained a flexural strength of 4,500 kPa (650 psi), but in no case until at least 7 days have elapsed after the placing of the concrete. In the absence of tests to determine the flexural strength, the additional material on the higher side shall not be placed until at least 14 days have elapsed after the placing of the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 7 ºC (45 ºF).

Behind abutments held at the top by the superstructure, no backfill or embankment shall be placed above the elevation of the backfill in front of such abutments until the superstructure is in place, the concrete cured and falsework removed from concrete spans. Backfill or embankment shall not be placed behind the walls of concrete culverts until the top slab is placed and cured. Backfill and

embankment behind abutments held at the top by the superstructure, and behind the sidewalls of culverts having a clear height of more than 1.5 m (5 ft), shall be carried up simultaneously behind opposite abutments or sidewalls, and at no time shall the fill behind one abutment or sidewall be more than 600 mm (2 ft) higher than behind the opposite one.

Backfill shall not be placed in water at closed abutments, culverts or retaining walls. The excavated area around these structures shall be pumped dry, and any mud or loose material within the excavated area shall be removed before placing backfill. At piers, backfill may be placed in water, providing no roadway embankment or slope wall is to be supported by the backfill and provided that both the water level and backfill are kept at approximately the same elevation on opposite sides of the pier. A time interval, approved by the Engineer, shall elapse before placing additional fill on one side of the pier, above the water surface.

Mechanical compaction of backfill will not be required around piers upon which no roadway embankment, slope wall or other highway appurtenance is to be placed and at those locations that are not adjacent to a highway, railroad or other improvement beneath the structure.

Except as specified, the procedures for placing and compacting the backfill shall be according to Articles 205.04 and 205.05. Except as described above, all backfill shall be placed in continuous horizontal layers not more than 200 mm (8 in.) in thickness, loose measurement, and each layer shall be compacted with a mechanical tamper of a type approved by the Engineer before the next layer is placed and the backfill shall be compacted to the density specified in Article 205.05. If the moisture content of the backfill material exceeds 110 percent of the optimum moisture content determined for this material, no additional material shall be placed without the permission of the Engineer.

A deposit of gravel or crushed stone, CA 5, 7, or 11, conforming to the gradation requirements of Article 1004.01, at least 600 mm (2 ft) in each direction shall be placed at the back of each drain hole in abutments, wingwalls, retaining walls and culvert sidewalls. The bottom of this deposit shall be 50 mm (2 in.) below the drain hole. All form boards or other obstructions shall be removed from the drains before such deposit is placed. The cubical deposit of coarse aggregate shall be completely enclosed in a fabric envelope. The fabric shall conform to the requirements of the applicable portions of section 1080 and section 282 with either the 200 grams per square meter or 270 grams per square meter (6 oz. or 8 oz. per square yard) material allowed. Free edges shall overlap by 300 mm (12 in.). No additional compensation will be allowed for this work.

502.11 Disposal of Excess Excavation and Unsuitable Material. Unsuitable material and suitable material in excess of that required for backfilling shall be disposed of by the Contractor according to Article 202.03.

502.12 Preservation of Channels. The natural stream bed adjacent to the structure shall not be disturbed without permission from the Engineer. No excavated material shall be placed in stream channels without permission of the Engineer, and then only upon condition that final disposal of the material will be made in such manner that there will be no obstruction of the channels. If any excavation is made in stream channels outside the area to be excavated for the structure, the Contractor

shall, at his/her expense, backfill all such excavations to the original ground surface or bed of stream with material satisfactory to the Engineer.

Within the limits of the right of way, excavated material, brush, logs and debris of any nature, shall be removed for the full length of the structure, so that the area will present a neat appearance and so that there will be no obstruction to the flow of the stream.

502.13 Reserved.

502.14 Method of Measurement.

(a) Contract Quantities. The requirements for the use of contract quantities shall conform to Article 202.07(a).

(b) Measured Quantities. None of the excavation included within the volume limits of Channel Excavation or Earth Excavation will be included in the measurement of excavation for structures.

For Structure Excavation, Rock Excavation for Structures, Cofferdam Excavation and Removal and Disposal of Unsuitable Material, measurement for payment will be made in cubic meters (cubic yards) of the excavation and removal actually performed within the limitations specified.

Structure Excavation will be measured in its original position. Horizontal dimensions will not extend beyond vertical planes 600 mm (2 ft) outside of the edges of footings of bridges, walls and corrugated steel plate arches. The vertical dimension for Structure Excavation will be the average depth from the surface of the material to be excavated to the bottom of the footing or foundation seal as shown on the plans or ordered in writing by the Engineer.

Rock Excavation for Structures, other than boulders and masonry or timber, will be measured in its original position and the volume in cubic meters (cubic yards) computed by the method of average end areas.

Rock excavation for footings, foundation seals or other structures, except pipe structures, will be measured vertically from the top of the rock to the elevation of the bottom of the rock or bottom of the structure, whichever occurs first, and horizontally within the perimeter of the structure to be placed. Rock excavation for pipe structures will be measured vertically from the elevation of the top of the rock to the specified elevation below the bottom of the pipe and horizontally for the width of the trench specified for placing the pipe. When the depth of rock removal below the bottom of a pipe structure is not otherwise specified, the rock shall be removed to 200 mm (8 in.) below the bottom of the pipe; except for water service lines and pipe underdrains, the depth of removal shall be 75 mm (3 in.) below the bottom of the pipe. Rock excavation for storm sewers which are jacked in place will be measured as the volume actually moved, except that the horizontal dimension will not be greater than the external diameter of the pipe plus 300 mm (12 in.) and the vertical dimension will not be greater than the external diameter of the pipe plus 300 mm (12 in.) above the pipe and

200 mm (8 in.) below the pipe, unless the total vertical dimension is less than 1.2 m (4 ft), in which case 1.2 m (4 ft) may be used.

Where it is necessary to construct sumps in rock, measurements shall include the areas and depths required for such sumps. Boulders and isolated rocks, 0.5 cu m (1/2 cu. yd.) or more in volume, will be measured individually and the volume computed from average dimensions taken in three directions. The quantity of masonry or timber to be paid for will be the volume of such material actually removed within the limits of the excavation as specified.

Cofferdam excavation, where specified, will be measured in cubic meters (cubic yards) in its original position within the cofferdam sheeting. The horizontal dimensions used in computing the volume will not extend beyond vertical planes 600 mm (2 ft) outside of the edges of the pier footings or 1.2 m (4 ft) outside of the faces of the pier wall whichever is greater. The vertical dimensions will be the average depth from the surface of the material to be excavated to the elevation shown on the plans for bottom of the footing or foundation seal, or as otherwise determined by the Engineer as the bottom of the excavation.

Excavation outside the maximum dimensions specified will not be measured for payment. The Contractor shall notify the Engineer a sufficient time in advance of starting excavation so that the necessary measurements can be made.

Excavation, except excavation of rock and excavation of unstable and unsuitable materials, for the construction of slopewalls, pipe culverts, and concrete box culverts will not be measured for payment.

502.15 Basis of Payment. Except as provided, the work specified in this Section will not be paid for as a separate item. Where excavation for structures is not specified, the cost of the excavation shall be considered as included in the contract unit price for the class of concrete involved, or other unit price item of the work for which it is required.

Structure Excavation and Cofferdam Excavation, when specified, will be paid for at the contract unit price per cubic meter (cubic yard) for STRUCTURE EXCAVATION and COFFERDAM EXCAVATION.

When material classified as Rock Excavation for Structures is encountered and when the contract contains a unit price for Rock Excavation for Structures, the excavation of material classified as such, regardless of depth, will be paid for at the contract unit price per cubic meter (cubic yard) for ROCK EXCAVATION FOR STRUCTURES. When the contract does not contain a unit price for Rock Excavation for Structures, it will be paid for according to Article 109.04.

Removal and disposal of unstable and/or unsuitable material will be paid for according to Article 202.08.

Where it is necessary to excavate below the plan bottom of footing elevation, the basis of payment shall be as follows:

For the first 75 mm (3 in.), the excavation will be paid for according to the contract unit prices for the type of excavation involved. The cost of furnishing and placing the crushed stone, gravel or other material, shall be included in the unit price bid for the class of concrete involved.

When it is necessary to excavate more than 75 mm (3 in.) below the plan bottom of footing elevation, the excavation will be paid for at the contract unit prices for the class of excavation involved. Furnishing and placing the crushed stone, gravel, or other material below the first 75 mm (3 in.) will be paid for according to Article 109.04.

Cofferdams, when specified, will be paid for at the contract unit price each for COFFERDAMS, at the locations specified. The size and details of the cofferdam shall meet the approval of the Engineer and no extra compensation will be allowed for a cofferdam of excessive size. Excavation from within a cofferdam added to the contract will be paid for at the unit price bid for cofferdam excavation, except if there is no item for Cofferdam Excavation in the contract, the excavation will be paid for according to Article 109.04.

When added to the contract by written permission of the Engineer, the cofferdams will be paid for according to Article 109.04. The excavation within the added cofferdam will be paid for at the contract price for Cofferdam Excavation. If a unit price is not provided in the contract, the excavation will be paid for according to Article 109.04.

Tree Removal and Protection of Existing Plant Material will be paid for according to Section 201.

Additional suitable material required for backfilling within the roadbed, will be paid for according to Article 109.04.

SECTION 503. CONCRETE STRUCTURES

503.01 Description. This work shall consist of the construction of all cast-in-place concrete structures.

503.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item		Article/Section
(a)	Portland Cement Concrete (Note 1)	1020
(b)	Protective Coat	1023
(c)	Preformed Expansion Joint Filler	1051.01 - 1051.09
(d)	Waterproofing Material	1060.01 - 1060.08
(e)	Nonmetallic Water Seals	1054
(f)	Elastomeric Bearings	1083
(g)	Preformed Elastomeric Compression Joint Seals for Concrete	1053
(h)	Neoprene Expansion Joint	1052
(i)	Reinforcement Bars	508

Note 1. At the Contractor's option, Class SI Concrete may be used when Class MS Concrete is specified.

503.03 Equipment. Equipment shall meet the requirements of the following Articles of Section 1100 - Equipment:

Item		Article/Section
(a)	Concrete Mixers	1103.01
(b)	Batching and Weighing Equipment	1103.02, 1103.03
(c)	Water Supply Equipment	1103.11
(d)	Hand Vibrator	1103.17(a)
(e)	Vibrating Screed	1103.17(g)
(f)	Membrane Curing Equipment	1101.09(b)
(g)	Finishing Machine	1103.13(a)

CONSTRUCTION REQUIREMENTS

503.04 Excavation and Fill. All excavation and backfill required for the construction of concrete structures shall be performed according to Section 502. Substructures, foundations and footings shall be constructed in open excavation wherever practicable.

503.05 Falsework. The Contractor shall submit detailed plans for falsework for examination by the Engineer. If such plans are not satisfactory to the Engineer, the Contractor shall make such changes in them as may be required, but it is understood that the Engineer's concurrence in the use of the plans as submitted or corrected shall in no way relieve the Contractor of responsibility for obtaining satisfactory results.

For continuous concrete slab and girder bridges, falsework and forms shall be provided for the full length of each continuous unit and the full width of the structure.

For calculating the strength of falsework, a mass (weight) of 2400 kg/cu m (150 lb/cu ft) shall be assumed for the concrete. The design of the false work shall take into account the weight of the concrete and also other loads incidental to the construction operations. All false work shall be designed and constructed to provide the necessary rigidity and to support the imposed loads without appreciable settlement or deformation. The Contractor shall make allowance for the deflection of forms and for shrinkage and settlement of falsework, in addition to the allowance for the amount of dead load deflection and camber shown on the plans. A method satisfactory to the Engineer shall be used to detect any settlement that may occur during the placing of the concrete.

Falsework bents shall generally be founded upon piling driven to a capacity sufficient to support the load without appreciable settlement. If the soil is firm and well compacted, the Contractor may, as an alternate, place falsework bents upon concrete footing or mud sills of sufficient size that the pressure on the soil will not exceed 145 kPa (1 1/2 tons per sq ft) or the Contractor may support falsework from the piers or abutments, provided sleeves for any tie bolts can be cast into the concrete and the method proposed meets the approval of the Engineer. Sleeves or other appurtenances cast into the concrete shall be constructed so as to permit their

removal to a depth of at least 40 mm (1 1/2 in.) from the face without injury to the concrete. Drilling into existing piers or abutments that are to remain as a part of the final structure will not be permitted for the support of falsework. The Engineer may require the Contractor to use screw jacks or hardwood wedges to take up any settlement in the form work, either before or during the placing of the concrete.

Falsework supporting cast-in-place concrete, and forms supporting concrete floor slabs on beams shall remain in place until tests show that the concrete has attained a flexural strength of 4,500 kPa (650 psi) and also until at least 7 days have elapsed from the time placement of concrete is completed on the span or series of continuous spans. If high-early-strength portland cement is used, this period may be reduced as directed by the Engineer. In the absence of tests to determine the flexural strength, the falsework shall remain in place until at least 14 days have elapsed after the placing of the concrete, exclusive of days in which the temperature falls below 7 ºC (45 ºF).

The Contractor shall leave falsework in place for a longer period of time when required by the Engineer. No superimposed load, either dead or live, will be allowed upon the bridge during the period the falsework is required to remain in place. The falsework shall not be removed from any span of a cast-in place continuous unit until the concrete in the entire unit has been cured for the required period of time. If longitudinal expansion joints are provided in the roadway of any superstructure, the falsework shall not be released under one portion adjacent to such a joint until the concrete in that portion has attained the required strength and the concrete has been placed in the portion on the opposite side of such joint. The falsework shall not be removed from the portion on either side of such joint until all the concrete has set sufficiently to avoid damage to the concrete adjacent to the joint.

Falsework shall be removed in such a manner as to permit the concrete to take uniformly and gradually the stress due to its mass (weight).

503.06 Forms. For continuous concrete slab and girder bridges, forms shall be provided for the full length and width of each continuous unit formed. The Contractor shall, when required, submit detailed plans for forms for review and approval by the Engineer.

A mass of 2400 kg/cu m (weight of 150 lb/cu ft) shall be assumed for the concrete in the design of the forms. The design of the forms shall provide for accommodation of incidental loads, settlement, deadload deflection, shrinkage, and deformation of the form components. The forms shall provide the structural capacity required to produce finished concrete to the lines and grades specified on the plans. Forms shall be constructed of wood, metal, or other material approved by the Engineer.

Wood forms for exposed surfaces shall be made of dressed lumber or plywood, with or without a form liner of a type approved by the Engineer. Except for curved and special surfaces, wood forms shall be surfaced on both sides and both edges and shall be sized to uniform thickness.

Metal forms shall be of such thickness that they will remain true to shape. All bolts and rivet heads in contact with concrete shall be countersunk. Clamps, pins and other connecting devices shall be designed to hold the forms rigidly in place and

to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or line up properly shall not be used. Special care shall be exercised to keep metal forms free from rust, grease or other foreign matter which would discolor the concrete.

Forms shall be filleted at all sharp corners. Triangular moldings used for fillets or V-shaped notches shall have 2 equal sides. Where the size of the molding is specified, the dimension stated shall be the width of each of the equal sides.

Moldings for fillets and notches shall be 20 mm (3/4 in.). The moldings for corners on handrails and handrail posts shall be 15 mm (1/2 in.). All moldings shall be cut with true edges, surfaced on all sides, and not warped, cracked or frayed. Forms shall be given a bevel or draft in case of all projections, such as girders and copings, to assure easy removal.

When directed by the Engineer, temporary openings shall be provided in the bottom of forms for cleaning out all extraneous material immediately prior to placing concrete.

Tie rods, bolts and anchorages, within the forms shall be constructed so as to permit their removal to a depth of at least 40 mm (1 1/2 in.) from the face without injury to the concrete. Wire ties, when used, shall be cut back at least 15 mm (1/2 in.) from the face of the concrete upon removal of the forms, except on surfaces not exposed to view, they may be cut flush. All fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest practicable size.

Forms shall be set and maintained to the lines and grades specified on the plans and in a manner approved by the Engineer until their removal. Prior to each reuse, forms shall be refurbished to the extent deemed necessary by the Engineer. The Engineer will be the sole judge as to the acceptability of forms for reuse.

Prior to bar placement, forms shall be coated with form oil or other bond breaking agent approved by the Engineer. In lieu of form oil, wood forms may be saturated with water immediately prior to placement of the concrete, when the surfaces are not exposed to view.

Forms shall remain in place until permission is obtained from the Engineer for their removal. The method of form removal shall not result in damage to the concrete. If forms are removed prior to the completion of the required curing period, curing shall be resumed with an approved curing method for the remainder of the curing period. Forms shall not be removed from the bottom of slabs, beams, or floors until a flexural strength of 4500 kPa (650 psi) has been obtained and also until at least 7 days have elapsed from the time placement of concrete is completed. In the absence of tests to determine the flexural strength, the forms shall remain in place until at least 14 days have elapsed after placing the concrete, exclusive of days the temperature falls below 7 ºC (45 ºF).

Forms used in casting concrete bridge floors will not be allowed to remain in place. All tie rods, bolts, anchorages, brackets and other forming hardware which is incorporated into the bridge deck shall be either epoxy coated or galvanized. Areas of epoxy coating which have been damaged due to welding shall be repaired.

If the Contractor intends to use cantilever forming brackets on the exterior beams or girders, the following procedures will be required to prevent beam twisting:

(a) The resulting force of the leg brace of the cantilever bracket shall bear on the web and within 150 mm (6 in.) of the bottom flange of the beam or girder.

(b) The exterior beams or girders, supporting cantilever forming brackets, shall be tied together at 1.2 m to 2.4 m (4 ft to 8 ft) intervals. On stage construction, where cantilever brackets are supported on one exterior line of beams or girders, this line shall be tied to the furthest opposite interior line. Ties shall be a minimum No. 15 (No. 4) epoxy coated reinforcement bars with threaded ends. Each tie bar shall be furnished with an approved tie bar stabilizing system consisting of adjustable end clips, lag studs, and turnbuckles. The tie clips shall mechanically attach to the outside fascia girder or interior girders as required for stage construction and the individual tie bar. The tie bars, turnbuckles, lag studs, and tie clips shall be furnished by the Contractor. The tie bars shall be placed parallel to and have the same clearance from the deck form work as required for the bottom transverse reinforcement. No welding will be permitted to the structural steel or stud shear connectors for the installation of the tie bar stabilizing system. After installation, the tie bar shall be tensioned with the turnbuckles until the bar does not vary from a straight line from center of end clip to center of opposite end clip.

    (1) If finishing machine rails are on the outside of the water table, the tie spacing shall not be greater than 1.2 m (4 ft) centers.

    (2) If finishing machine rails are on the top flange of the exterior beam, the tie spacing shall not be greater than 2.4 m (8 ft) centers.

    (3) Precast, prestressed concrete beams shall have ties not greater than 2.4 m (8 ft) centers regardless of where the finishing machine rails are placed.

    (4) Cross frames on steel girders which do not have a top strut shall not be considered a tie.

(c) Hardwood 100 mm x 100 mm (4 in. x 4 in.) blocks or material of an equivalent strength shall be wedged between webs of exterior and first interior beams within 150 mm (6 in.) of the bottom flanges at each location where the top of the beams are tied together.

This additional work for using the cantilever brackets will not be paid for separately as the Contractor has other options available to form the outside of the deck without using cantilevered hangers on the exterior beams. If the Contractor elects to use cantilever brackets with an alternate procedure, the Contractor shall submit design calculations and detailed plans for approval by the Engineer to verify that the alternate procedure will satisfy the requirements to prevent beam twisting.

503.07 Placing and Consolidating. No concrete shall be placed on ice, snow or frozen foundation material. The Contractor shall be responsible for all concrete damaged by low temperatures and shall remove and replace any concrete so damaged at his/her expense.

The method and manner of placing concrete shall be such as to avoid segregation or separation of the aggregates or the displacement of the reinforcement.

Open troughs and chutes shall extend as nearly as practicable to the point of deposit. Dropping the concrete a distance of more than 1.5 m (5 ft) or depositing a large quantity at any point and running or working it along the forms will not be permitted. The concrete for walls with an average thickness of 300 mm (12 in.) or less shall be placed with tubes so that the drop is not greater than 1.5 m (5 ft).

When concrete is conveyed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work, and arranged so that vibrations will not damage freshly placed concrete. Aluminum pipe or conduit will not be permitted in conveying or placing concrete. Mixed concrete shall be supplied so that the pumping equipment will be in continuous operation.

Placing of concrete shall be regulated so that the pressures caused by the wet concrete will not exceed those used in the design of the forms. Special care shall be taken to fill each part of the forms by depositing the concrete as near its final position as possible, to work the coarser aggregates back from the face and to force the concrete under and around the reinforcement bars without displacing them. After the concrete has taken its initial set, care shall be exercised to avoid jarring the forms or placing any strain on the ends of projecting reinforcement.

The concrete in all structures, and in all other concrete construction exclusive of pavement, shall be consolidated by internal vibration. A vibrator will be required except in thin sections or inaccessible locations where consolidation by internal vibration is not practicable.

The Contractor shall provide and use a sufficient number of vibrators to ensure that consolidation can be started immediately after the concrete has been deposited in the forms.

The vibrators shall be inserted into the concrete immediately after it is deposited and shall be moved throughout the mass so as to thoroughly work the concrete around the reinforcement and embedded fixtures and into the corners and angles of the forms. Vibrators shall not be attached to the forms, reinforcement bars, or the surface of the concrete.

Application of vibrators shall be at points uniformly spaced and not farther apart than twice the radius over which the vibration is visibly effective. The duration of the vibration at the points of insertion shall be sufficient to thoroughly consolidate the concrete into place, but shall not be continued so as to cause segregation. Vibration shall be supplemented by spading when required by the Engineer as is necessary along form surfaces and in corners and locations impossible to reach with the vibrators. In addition to the internal vibration required herein, formed surfaces which will be exposed to view after completion of the work shall be spaded with a spading tool approved by the Engineer, to prevent the formation of voids in the surface.

The provisions of this Article shall also apply to precast piling, concrete cribbing, and other precast members, except as otherwise specified in Article 504.06(c)(4) for precast, prestressed concrete members. If approved by the Engineer, the manufacturer's methods of vibration may be used.

Concrete shall be placed in continuous horizontal layers. When it is necessary by reason of an emergency to place less than a complete horizontal layer in one operation, such layer shall terminate in a vertical bulkhead. In order that the concrete will not be injured and that there shall be no line of separation between the batches, the separate batches shall follow each other closely, and in no case shall the interval of time between the placing of successive batches be greater than 20 minutes. If ready-mixed concrete is used, the requirements of Article 1020.11 shall apply. Delivery of mixed concrete shall be regulated so that there will not be an interruption of more than 20 minutes duration in the placing of concrete in the forms.

The operations of depositing and consolidating shall be conducted so that the concrete after removal of the forms will be reasonably free from aggregate pockets and honeycomb. All exposed surfaces shall be smooth and dense. All unexposed surfaces shall be dense and free from excessive depressions or projections. All concrete which does not meet these requirements shall be removed and replaced by the Contractor or shall be repaired to the satisfaction of the Engineer.

503.08 Depositing Concrete Under Water. Concrete shall not be exposed to the action of water before setting, or deposited in water, except with the approval of the Engineer and under his/her immediate supervision.

When concrete is deposited under water, it shall be carefully placed in its final position by means of a tremie and shall not be disturbed after being deposited. Special care shall be exercised to maintain still water at the point of deposit. No concrete shall be placed in running water and all form work designed to retain concrete under water shall be watertight. The consistency of the concrete shall be carefully regulated and special care shall be exercised to prevent segregation of the materials. The method of depositing concrete shall be regulated so as to produce approximately horizontal surfaces.

The tremie shall consist of a tube having a diameter of not less than 250 mm (10 in.) and constructed in sections having flanged couplings fitted with gaskets. The means of supporting the tremie shall be such as to permit the free movement of the discharge end over the entire top surface of the work and shall be such as to permit it to be rapidly lowered when necessary to choke off or retard the flow. The discharge end shall be entirely sealed at all times and the tremie tube kept full to the bottom of the hopper. When a batch is dumped into the hopper, the tremie shall be raised slightly to induce the flow of concrete but the lower end shall be kept below the top of the deposited concrete until the batch is discharged. The flow shall then be stopped by lowering the tremie. The flow shall be continuous and in no case shall it be interrupted until the work is complete.

At the Contractor's option, pumping equipment may be used in lieu of a tremie to deposit concrete under water. The Engineer will approve the concrete pumping equipment and its piping before the work is started.

503.09 Construction Joints. Construction joints shall be made only at locations shown on the plans or approved by the Engineer, except in cases of breakdowns or other unforeseen and unavoidable delays in which case the Engineer will designate if the joint is to be bonded or unbonded.

Construction joints shown on the plans shall be unbonded. When not shown on the plans, their location shall be confined, as far as possible, to regions of low shearing stress and to locations that will be hidden from view. When possible, the location of construction joints shall be planned in advance and the concrete placed continuously from joint to joint. The reinforcing steel shall extend through such joints. If a construction joint is necessary in the sloped portion of a wingwall or similar location where a featheredge would result, the joint shall be constructed so as to produce an edge thickness of not less than 150 mm (6 in.) in the succeeding layer. No construction joint shall be placed within 450 mm (18 in.) of the top of any wall or pier unless the details of the work provide for a coping having a thickness of less than 450 mm (18 in.), in which case, at the option of the Engineer, a construction joint may be made at the under side of the coping.

The face edges of all joints which are exposed to view shall be carefully finished true to line and elevation. Shear keys, formed into or out from the surface of the previously placed concrete, or steel dowels, shall be used where required. Shear keys formed into the concrete shall be formed by the insertion and subsequent removal of beveled wood strips which shall be thoroughly saturated with water prior to insertion. Steel dowels may, at the discretion of the Engineer, be used in lieu of keys. The size and spacing of the keys and dowels will be as determined by the Engineer.

Between adjacent sections of retaining walls and abutment walls, a V-shaped groove shall be formed in the exposed face of the walls by the use of 15 mm (1/2 in.) triangular molding on each side of the joint.

Care shall be exercised not to injure the concrete or break the concrete-steel bond at any time. In constructing bridge floors where longitudinal joints are specified, a platform shall be constructed outside the longitudinal joints and supported on the lower slab form, and personnel will not be permitted to stand or walk on the projecting reinforcement bars until the concrete has hardened.

Longitudinal and transverse construction joints specified for bridge floors shall be constructed as specified in Article 503.09(b)(1).

Horizontal construction joints, when specified between the top of the bridge floor and the curbs, parapets, and sidewalks shall be constructed as specified in Article 503.09(b)(2).

The Contractor, subject to approval of the Engineer, may pour a bridge floor full width with horizontal bonded construction joints between the floor and curbs, parapets or sidewalks.

(a) Unbonded Construction Joints. Unbonded construction joints shall be made by forming or striking off the initial concrete placed to a true and even surface and allowing it to set. Loose material shall be removed. The new concrete shall be thoroughly consolidated against the existing concrete.

(b) Bonded Construction Joints. After the concrete has hardened, the cement paste shall be removed to create a prepared surface. The surface shall be prepared by washing with water under pressure or by sandblasting to expose clean, well bonded aggregate.

To facilitate the removal of the cement paste, the form in contact with the first pour or the exposed surface of the first pour, may be thoroughly covered with a surface retarder. When the surface retarder is applied directly to the fresh concrete surface, its application shall be completed within 30 minutes after concrete placement.

The surface retarder shall be a ready-to-use liquid compound that delays the set of a concrete surface, and shall be approved by the Engineer in advance of beginning the work. It shall produce results satisfactory to the Engineer and will be evaluated on the tests performed by the Engineer, and on the manufacturer's data recommendations.

Bonded construction joints, where required, shall be constructed using either of the following procedures.

(1) Immediately before placing the new concrete, the prepared surface shall be covered with a thin coat of mortar. The mortar shall be composed of 1 part portland cement and 1 part sand, and sufficient water to produce a thick fluid. All vertical and horizontal surfaces shall receive a thorough, even coating. No concrete shall be placed over dry mortar. Mortar that is allowed to become dry shall be removed and replaced at the Contractor's expense.

(2) The prepared surface of the existing concrete shall be wetted a minimum of one hour before application of the new concrete. The surface shall be maintained in a dampened condition during that period. Immediately before placing the new concrete, any excess water shall be removed.

503.10 Expansion Joints. Expansion joints shall be constructed as specified so as to permit freedom of movement. After all other work is completed, all thin shells of mortar and projections of the concrete into and around the joint space that are likely to spall under movement or prevent the proper operation of the joint shall be carefully removed.

(a) Open Joints. Reinforcement shall not extend across or into an open joint. Open joints in railings or under projecting portions of rail posts shall be formed with square corners unless beveled corners are specified. When not protected by metal expansion guards, open joints in floors and sidewalks shall be finished with an edging tool satisfactory to the Engineer.

(b) Filled Joints. When preformed joint filler is specified, the material may be any one of the types specified in Section 1051. The preformed joint filler shall be placed in correct position before the adjacent concrete on one side of the joint is poured. The joint filler shall be cut from the least practicable number of pieces to fit exactly and completely fill the space shown on the

plans. Loose fitting or open points between sections of filler or between filler and forms will not be permitted.

(c) Expansion Guards. The plates, angles or other structural shapes provided as expansion guards at joints between adjacent spans shall be accurately fabricated at the shop to conform to the section of the concrete floor or sidewalk. The fabrication shall conform to Section 505 and the painting shall conform to Section 506. Expansion guards shall be held securely in correct position during the placing of the concrete. The joint opening shall be adjusted according to the temperature at the time of placing so that the specified opening will be secured at a temperature of 10 ºC (50 ºF). The opening for each 10 m (100 ft) of bridge between the nearest fixed bearings each way from the joint shall be reduced 1 mm (1/8 in.) from the amount specified, for each 8 ºC (15 ºF) the temperature at the time of placing exceeds 10 ºC (50 ºF) and increased 1 mm (1/8 in.) from the amount specified, for each 8 ºC (15 ºF) the temperature at the time of placing is below 10 ºC (50 ºF).

(d) Sealed Joints. Preformed elastomeric compression joint seals, when specified, shall be of the size and shape shown on the plans. The seals shall be installed by suitable hand or machine tools and thoroughly secured in place with the approved adhesive which shall cover both sides of the seals over the full area in contact with the sides of the joint. The adhesive may be applied to the sides of the joint or the seals or both. The seals shall be installed in a compressed condition and shall at all times be below the level of the deck surface as shown on the plans. The seals shall be in one continuous piece for the full length of the joint. The continuous piece for installation shall not have more than one manufacturer's butt splice within its length. If the splice is torn or damaged it shall be repaired, prior to installation, using the manufacturer's recommended adhesive. Temperature limitations of the adhesive, as specified by the manufacturer, shall be observed. Joints shall be clean and free of foreign material immediately prior to installation of the seals.

Neoprene expansion joint seals shall conform to the details shown on the plans and as specified. The Contractor shall obtain installation instructions from the supplier of the expansion joint material and comply with the procedures specified in the installation of the joint. The Contractor shall form the concrete blockouts, set anchor bolts or studs, apply sealants and adhesives, and install joint units as shown on the approved shop drawings. Prior to placement of the deck concrete, the Contractor shall have written approval of joint details, concrete blockouts, anchor bolt placement, the seat conditions and the cleanout of the joint opening. The shop drawings, along with joint details, shall include details of the concrete blockout if required for the installation, a layout plan of the joint units to be used, and the spacing and location of the anchor bolts or studs. Details of installation shall meet with the approval of the Engineer.

Anchor bolts shall be set in their proper location by the use of a suitable template and shall be cast-in-place except as otherwise shown or specified. All loose, long, or misaligned anchor bolts shall be corrected in a manner approved by the Engineer. Concrete inserts will not be permitted as a

substitute for cast-in-place or epoxy-grouted anchor bolts. When neoprene expansion joint pads are to be seated on structural steel joint elements, automatically end welded threaded studs, as shown on the plans, shall be used.

All forms and debris shall be removed from the joint opening. Concrete or metal surfaces on which the neoprene expansion joints are to be set shall be dry; clean and free from dirt, grease, loose concrete, and contaminants; level; and sound with no broken or spalled concrete. Adjacent joint seats shall be on a straight plane with each other. Joint seals shall not be placed until the Engineer has checked the seats with a straightedge and approved the alignment. Misalignments shall be corrected by grinding or other approved procedures, including, if necessary, concrete removal and replacement to obtain proper alignment. Joint opening and blockout will be approved for conformance to plan dimensions prior to placement of joint seals.

The neoprene molded sealing element shall be furnished and installed in one continuous, unbroken length for the entire joint length including parapets, curbs and walls. The continuous seal shall be installed in an adhesive/sealant bedding compound in the blockout as shown on the plans. The adhesive/sealant shall be liberally applied over the entire blockout or metal seat area as the sealing element is set into it. The anchor blocks shall then be set in position over the seal with the nuts torqued to at least 90 N m (65 ft lb). A minimum of 24 hours after initial installation, the nuts shall be retorqued to the initial 90 N m (65 ft lb). Prior to filing the space in the bolt wells, the Engineer's inspection of the anchor fasteners and tightening of the units will be required. Any wells sealed without the Engineer's approval shall be opened and redone at the Contractor's expense. Full-length anchor block units, with tongue and groove or other positive type interconnects, will be required, except as otherwise shown on the approved shop drawings. All joints between units, around connecting bolts, and cavity plugs shall be sealed with a block flexible epoxy sealant in a neat manner to seal out water and protect against corrosion. Neoprene surfaces to be in contact with adhesive or sealant shall be cleaned with an acceptable solvent as recommended by the manufacturer or cleaned with a wire brush, prior to installation to provide a bonding surface for the adhesive or sealant.

Where longitudinal joints intersect with transverse joint seals, a positive seal shall be provided by flattening and extending the longitudinal joint neoprene seal element under the transverse joint pad. When this procedure is not practical, a separate neoprene apron, bonded to the longitudinal seal element, may be used.

The finished joint shall present a smooth, neat appearance with no protruding bolts or rough joints. Excess sealant shall be wiped or scraped away before it becomes hard. Upon completion of an entire joint, the Contractor shall grind any uneven end butt connections flush. Any openings between butt ends not showing sealant to the top shall be cleaned and filled with sealant. Where the joint pads are inset into the concrete blockouts, the edges between the concrete and the pads shall be sealed with sealant. When the bridge deck is to be waterproofed and surfaced, the installation of

the joint shall be completed prior to placement of the deck waterproofing and bituminous concrete surfacing.

503.11 Anchor Bolts and Bearings. Anchor bolts shall conform to Article 505.04(u). Metal bearings shall be fabricated according to Article 505.04(l). Anchor bolts and bearings shall be set according to Article 505.08(f). When bed plates are set in portland cement mortar, no superstructure or other load shall be placed thereon until this mortar has been allowed to set for a period of at least 96 hours, with adequate provision being made to keep it well moistened during this period.

Elastomeric bearings shall be furnished in assemblies and installed as shown on the plans and shall be packaged, crated or wrapped in such a manner so that the elastomeric bearing assembly will not be damaged during handling, transporting or shipping. Any bearing damaged during handling, transporting, shipping or installing shall be replaced by the Contractor at his/her own expense. Unless otherwise approved by the Engineer, the elastomeric bearing assemblies shall be furnished as a complete unit from one manufacturing source. Exposed edges and other portions of the structural steel bearing plates shall be painted according to Article 506.05. During cleaning and painting, the stainless steel and TFE sheet sliding surfaces and the elastomer shall be protected from abrasion and paint.

503.12 Drainage Openings. Drain holes, 75 mm (3 in.) in diameter, spaced approximately 2.4 m (8 ft) apart horizontally and 1.8 m (6 ft) apart vertically, shall be constructed in abutment walls, wingwalls, retaining walls, and culvert sidewalls. A cubical deposit of gravel or broken stone shall be placed behind each drain hole according to Article 502.10. The lower line of drain holes shall be 600 mm (2 ft) above the flow line or grade line.

The locations of roadway drains on all concrete superstructures or floors shall be adjusted so as to prevent the discharge of drainage water against any portion of the structure, or directly onto any railroad, highway or unprotected embankment beneath the structure.

Drains consisting only of openings formed in the floor and curbs shall be provided with a surrounding drip notch in the bottom surface of the slab as provided in Article 503.06.

Metal floor drains shall be as specified and shall be placed and securely fastened in position before the concrete is placed.

503.13 Nonmetallic Water Seals. Nonmetallic water seals shall be installed as specified. Provisions shall be made to adequately support the water seal during construction. The projecting edges and ends of partially embedded water seals shall be protected from damage.

When splices are required, they shall be made by heating or vulcanizing to form continuous watertight joints. For the polyvinylchloride water seal, the heat shall be sufficient to melt but not char the plastic.

503.14 Foundations and Footings. All footings shall be as specified except that the Engineer may order, in writing, such changes in the footings as may be necessary to secure a satisfactory foundation.

Piling may be added or deleted from footings of substructures when the natural foundation conditions encountered make it necessary. The footings will be redesigned, when necessary, to permit the addition of piles or to spread the footing for stable bearing.

The final decision as to the elevation at which footings shall be placed and as to the requirements for piling will be made by the Engineer as the excavation progresses or after a test pile has been driven.

When concrete footings are constructed in excavation other than rock, forms shall be provided for all vertical surfaces, except when the foundation material may be excavated accurately to the lines and grades required and will remain true to such lines and grades until the concrete is placed in the excavated space, the Engineer may permit forms to be omitted. When forms are omitted, the entire excavated space shall be filled with concrete to the elevation of the top of the footing. Where concrete footings are to be constructed in rock excavation, forms shall be omitted and the entire space, excavated in rock according to Article 502.05, shall be filled with concrete up to the top of the footing, or to the top of the rock if the latter is lower. In all cases, where sumps are required for the disposal of water, they shall be constructed outside the footing areas and forms shall be used for the footings at each sump. When footings are placed without forms, the additional concrete required to fill any irregularities or other excavated space outside the specified lines of the footings shall be placed at the entire expense of the Contractor.

Except for joints specified, the concrete footing for each substructure unit shall be placed as a monolith. Vertical construction and expansion joints shown on the plans in abutments and wing walls shall not extend through the footing. In retaining walls or other structures, where joints extend through the footing, the water seal required in the joints between adjacent sections of wall need not extend below the top of the footing.

Footings shall be allowed to set for a period of time which is sufficient to preclude the possibility of damage by subsequent work.

If it is necessary to increase or decrease the depth of the foundations from that shown on the plans, the thickness of the wall where it joins the footing shall be increased or decreased the same amount per meter (foot) as the main wall increases per meter (foot) of its height as shown on the plans.

If the total height of the wall is changed by more than 600 mm (2 ft) from that shown on the plans, the wall and footing will be redesigned.

503.15 Foundation Seals in Cofferdams. When conditions are encountered which render it impractical to dewater a cofferdam before placing concrete, the Contractor will be permitted to construct a concrete foundation seal of such dimensions as may be necessary. Foundation seals will be paid for only when called for by the plans or authorized in writing by the Engineer. Their use will not be authorized except where properly constructed cofferdams cannot be dewatered satisfactorily by ordinary means.

The foundation seal shall be constructed below the elevation of the footing as shown on the plans, and will not be considered a part of the footing. Foundation seals shall be designed to withstand the hydrostatic pressure, taking into account the resistance afforded by the cofferdam and foundation piles. Foundation seals shall be constructed of Class SC Concrete according to Section 1020. The concrete in each foundation seal shall be placed in one continuous operation and according to Article 503.08.

The foundation seal shall not be omitted without written consent of the Engineer. Such consent will in no way relieve the Contractor of any responsibility for the safe construction of the foundation, or for any damage done as a result of the omission of the foundation seal.

503.16 Surface Finish. The external surface of all concrete shall be thoroughly worked during the operations of placing in such a manner as to work the mortar against the forms to produce a smooth finish free of honeycomb and with a minimum of water and air pockets.

Depressions resulting from the removal of ties, and holes left by attachments to rod or bolt anchorages shall be carefully and neatly pointed with a mortar of sand and cement mixed in the proportions used in the concrete being treated.

Air pockets or rough places larger than 15 mm (1/2 in.) diameter occurring in any surface shall be pointed as specified in the foregoing paragraph. Honeycombed areas shall be chipped out by the Contractor and inspected by the Engineer before being pointed. Pointed areas mentioned in this paragraph shall then be given a normal finish.

(a) Normal Finish. All surfaces that will be exposed to view after completion of the work, except surfaces specified in Article 503.17(c) and (d), shall be given a normal finish. This shall consist of the removal of fins, rough spots, stains, hardened mortar or grout, and form lines by rubbing with a No. 16 carborundum stone or an abrasive of equal quality without materially changing the texture of the surface. The rubbing shall be continued sufficiently to remove all roughness and projections.

When the surface of concrete that will be exposed to view shows a film of oil left from an excess of oil on the forms, or the concrete is oil-stained, or is otherwise not of uniform color, the Engineer may require the Contractor to employ the following cleaning method. Mix 1 part portland cement and 1 1/2 parts fine sand with sufficient water to produce a grout having the consistency of thick paint. Portland cement from the source of the cement used in the concrete shall be used in the grout. Wet the surface of the concrete sufficiently to prevent absorption of water from the grout and apply the grout uniformly with brushes, completely filling air bubbles and holes. Immediately after applying the grout, float the surface with a suitable float, scouring the wall vigorously. While the grout is still plastic, the surface shall be finished with a sponge rubber float removing all excess grout. This finishing shall be done at the time when grout will not be pulled from holes or depressions. Next, allow the surface to dry thoroughly, then rub it vigorously with dry burlap to completely remove any dried grout. There shall be no visible film of grout remaining after this rubbing. The entire cleaning

operation for any area must be completed the day it is started. No grout shall be left on the wall overnight. No cleaning operations shall be undertaken until all patching and filling of tie holes has been done.

(b) Rubbed Finish. When specified, a rubbed finish shall be provided. Surfaces to be rubbed shall be designated on the plans or in the Special Provisions.

Surfaces requiring a rubbed finish shall be thoroughly wet with a brush and rubbed with a No. 16 Carborundum stone, or an abrasive of equal quality, bringing the surface to a paste. The rubbing shall be continued sufficiently to remove all roughness and projections, producing a smooth dense surface free from pits and irregularities. The material which has been ground to a paste in the above process shall be carefully spread or brushed uniformly over the rubbed surface and permitted to reset. The final finish shall be obtained by a thorough rubbing with a No. 30 Carborundum stone, or an abrasive of equal quality, first wetting with a brush as for the initial rubbing. The finish rubbing shall continue until the entire surface is of a smooth texture and uniform in color.

(c) Bearing Seats. Seats for bridge bearings shall be finished smooth at the proper plane and elevation with a steel trowel. After the water sheen has disappeared, the surface shall be given a final finish by brushing with a whitewash brush. The brush shall be drawn across the seat longitudinally with the bridge deck, with adjacent strokes slightly overlapping, producing a uniform, slightly roughened surface with parallel brush marks.

503.17 Concrete Superstructures. The concrete in any cast-in-place superstructure or floor shall be placed in one continuous operation between expansion or construction joints specified. Standby equipment of sufficient capacity shall be available so that there will be no delay in placing of the concrete once the operation has started. Sidewalks, curbs or medians shall be placed monolithically with the floor or superstructure unless a construction joint between them is specified.

(a) Concrete Floors on Steel or Precast Concrete Superstructures. Before concrete floors are placed on a previously erected superstructure, all falsework supporting the superstructure members shall have been removed. Concrete floors shall be constructed so that, after taking into account any anticipated deflection of the supporting members due to the weight of the floor as shown by the deflection diagram on the plans, the top of the finished floor shall be at the specified elevation.

(b) Cast-in-place Concrete Superstructures. Concrete parapets and railings, and those concrete curbs, sidewalks, and medians not placed monolithically with the superstructure, shall not be placed until after the superstructure has been completed and the falsework removed.

(c) Bridge Floors. Cast-in-place concrete bridge floors shall be finished and textured in the following manner:

(1) Floors 30 m (100 ft) or more in length.

a. Finishing. After the concrete is placed and consolidated, it shall be struck off and finished with a power driven finishing machine.

The finishing machine will not be required for that portion of the floor outside of the outer construction joints shown on the plans, when the distance from the construction joint to the parapet flow line is less than 2 m (6 ft).

Long handled floats having blades not less than 1 m (3 ft) in length and 150 mm (6 in.) in width may be used to smooth and fill occasional porous or open-textured areas in the floor surface, but shall not be used to float the entire surface. The Contractor shall take immediate corrective action to eliminate the causes of the porous or open-textured areas as they occur.

The Contractor may, at his/her option, transversely float the entire floor surface with a hand-operated float having blades not less than 3 m (10 ft) in length and 150 mm (6 in.) in width.

Unusual jobsite conditions which occur during the floor placement and may require finishing or floating techniques not specified above shall be approved by the Engineer.

Water will not be permitted to be applied to the floor surface unless it can be demonstrated to the Engineer that workability cannot be obtained. If water is permitted by the Engineer, it shall be applied in a fine mist by means of a sprayer, at a distance not to exceed 300 mm (12 in.) from the surface. Application by brushes or any other method that concentrates water will not be permitted.

b. Surface Test. After the finishing has been completed and while the concrete is still plastic, the surface of the concrete shall be tested for trueness with a 3 m (10 ft) straightedge. The Contractor shall furnish and use an accurate 3m (10 ft) straightedge which has a handle not less than 1 m (3 ft) longer than 1/2 the width of the floor. The straightedge shall be held in contact with the surface and passed gradually from one side of the floor to the other. Advance along the floor shall be in successive stages of not more than 1/2 the length of the straightedge. Any depressions found shall be immediately filled with freshly mixed concrete, struck off, consolidated and refinished. High areas shall be cut down and refinished. The straightedge may be used to finish and seal the floor surface when approved by the Engineer. Special attention shall be given to assure that the finished profile of the surface across joints meets the requirements for smoothness. Straightedge testing of the floor shall continue until the entire surface is found to be free from variations from the straightedge, and the floor conforms to the required grade and cross-section.

If the Contractor chose to transversely float the entire floor surface with the 3 m (10 ft) hand float and surface corrections made, additional straightedge testing will not be required.

(2) Floors under 30 m (100 ft) in length.

a. Finishing. After the concrete is placed and consolidated, it shall be struck off with a vibrating screed allowing for camber, if required. The vibrating screed shall be of a type approved by the Engineer. A slight excess of concrete shall be kept in front of the cutting edge at all times during the striking off operation.

The floor surface shall be finished with long handled floats having blades not less than 1 m (3 ft) in length and 150 mm (6 in.) in width to produce a surface conforming to the plan cross section, of uniform texture, free from porous areas and a smoothness meeting the specification requirements.

Water will not be permitted to be applied to the floor surface unless it can be demonstrated to the Engineer that workability cannot be obtained. If water is permitted by the Engineer, it shall be applied in a fine mist by means of a sprayer, at a distance not to exceed 300 mm (12 in.) from the surface. Application by brushes or any other method that concentrates water will not be permitted.

b. Surface Tests. After the finishing has been completed, the floor surface shall be tested by straightedge according to Article 503.17(c)(1)b.

(3) Surface Smoothness.

a. All concrete bridge floors shall be tested for trueness at the expiration of the required curing or protection period. The entire surface shall be tested by means of a 5 m (16 ft) straightedge placed parallel to the grade line and touching the surface. Variations measured from the face of the straightedge to the surface of the floor shall not exceed 5 mm (3/16 in.). Variations greater than 5 mm (3/16 in.) shall be removed by grinding or cutting. Bushhammering or any method involving impact shall not be used. Grinding or cutting shall not be done until the concrete is at least 7 days old.

(4) Texture. All concrete bridge floors shall be textured by use of a burlap or artificial turf carpet drag in the plastic state followed by transverse diamond saw cut grooving after the bridge floor has cured.

a. Plastic Texture. The burlap or artificial turf shall be suitably attached to a bridge, riding on rails, or other approved device that will permit control of the time and rate of texturing. The burlap or artificial turf carpet shall have a length equal to the width of the pour or from face-to-face of curblines, as applicable. The burlap or carpet shall be laid on the concrete surface and dragged, parallel to the centerline of the roadway, in the direction that the deck is being laid with approximately 600 mm (2 ft) of its width in contact with the concrete surface. The drag shall be operated so as to produce a uniform appearing finish meeting the approval of the Engineer. The

burlap shall be double thickness and shall be kept saturated with water while in use. The artificial turf carpet may be weighted, if necessary, for maintaining intimate contact with the concrete surface.

b. Grooving. The grooving operation shall not be started until after the expiration of the required curing or protection period and after the operation of straightedging the deck surface and correcting excessive variations by grinding or cutting has been completed.

The grooves shall be cut into the hardened concrete, perpendicular to the centerline, using mechanical saw device equipped with diamond blades that will leave grooves 3 mm wide and 5 mm ± 1.5 mm (1/8 in. wide and 3/16 in. ± 1/16 in.) deep. The Contractor shall have the option of constructing the grooves at either a random spacing of 15 mm (5/8 in.) to 30 mm (1 1/4 in.) centers with an average spacing of 22 mm (7/8 in.) or a uniform spacing of 20 mm (3/4 in.) centers. The grooving shall be stopped 300 mm (12 in.) from the faces of curbs or parapets and 50 mm ± 25 mm (2 in. ± 1 in.) from deck drains and expansion joints. If grooving must be performed as part of stage construction, the grooving may be deferred until at least two adjacent lanes have been poured.

The removal of slurry shall be continuous throughout the grooving operations. The grooving equipment shall be equipped with vacuum slurry pickup equipment which shall continuously pick up water and sawing dust, and pump the slurry to a collection tank. The Contractor shall dispose of the slurry off site according to Article 202.03.

Cleanup shall be continuous throughout the grooving operation. All grooved areas of the deck shall be flushed with clear water as soon as possible to remove any slurry material not collected by the vacuum pickup. Flushing shall be continued until all surfaces are clean to the satisfaction of the Engineer.

(d) Sidewalks, Curbs and Medians on Bridges. Forms for concrete sidewalks, curbs and medians whether placed monolithically with the bridge floor or superstructure, or with a construction joint separating them from the floor or superstructure, shall be adjusted to correct elevation, camber and alignment after the floor or superstructure has been placed and prior to the completion of the curbs, sidewalks and medians. After the concreting has been completed, they shall be struck off and finished with floats and trowels.

The edge of curbs, or walks not more than 600 mm (2 ft) in width, shall be either beveled by the use of 20 mm (3/4 in.) triangular moulding at the top of the face forms or edged with an edging tool. The edge of walks over 600 mm (2 ft) in width shall be finished with an edging tool satisfactory to the Engineer. Transverse construction joints shall not be edged and transverse grooves shall not be provided.

The top surface of all walks shall be floated and troweled to a smooth finish with a steel trowel. After the water sheen has disappeared, the surface shall be given a final finish by brushing with a bristle brush. The brush shall be drawn across the walk, at right angles to the edge of the walk, with adjacent strokes slightly overlapping, producing a uniform surface moderately roughened by parallel brush marks. The stiffness of the bristles and the time at which the surface is finished shall be such as to leave well defined brush marks. The brush shall be kept clean at all times to avoid depositing mortar picked up by it during previous strokes.

(e) Concrete Parapets and Railings. Concrete parapets and railings shall not be placed until the falsework for the span has been released, rendering the span self-supporting.

Special care shall be exercised to secure smooth, tight fitting forms which can be held rigidly to line and grade and removed without injury to the concrete. All moulding, panel work and bevel strips shall be straight and true, with neatly mitered joints, and all corners in the finished work shall be true, sharp and clean cut. Alignment of forms and grade of top chamfer strips shall be checked immediately after the placing of concrete in the forms. Rail posts, openings and panels shall be constructed with vertical lines, regardless of the grade on which the railing is constructed.

(1) Slipforming. At the option of the Contractor, concrete parapets shall be constructed by slipforming in lieu of the conventional forming methods. The slipform machine shall have automatic horizontal and vertical grade control and be approved by the Engineer. Slipformed parapets shall be cured according to either Article 1020.13(a)(3) or Article 1020.13(a)(4) except that only Membrane Curing Type I compatible with linseed oil will be permitted between November 1 and April 15.

Additional tying of the rebar cage will be necessary to maintain rigidity during concrete placement. After the slipform machine has been set to proper grade and prior to concrete placement, the clearance between the slipform and reinforcement bars shall be checked by the Contractor in the presence of an inspector. This dry run check shall be made for the full distance that is anticipated to be placed in the subsequent pour. Aluminum cracker plates and guardrail inserts shall be securely tied in place. In lieu of chamfer strips at horizontal and vertical edges, radii may be used.

If the Contractor desires a greater concrete cover over the reinforcement bars for the slipform operation, the parapet cross-sectional area shall be revised according to the Standard for Concrete Parapet Slipforming Option.

The Contractor may use additional stiffening reinforcement bars to prevent movement of the required reinforcement bars during pouring. Clearances for these bars shall be the same as shown for the required bars and bars shall be epoxy coated. If the additional reinforcement is used it shall be at no additional cost to the Department.

The Contractor may use alternate reinforcement as shown in Standard for Parapet Slipforming Option at no additional cost to the Department. The alternate reinforcement shall be epoxy coated.

The top portion of the joint shall be sawcut to the full depth as shown on the plans within 4 to 24 hours after concrete placement. The sawcut shall be approximately 10 mm (3/8 in.) wide and shall be performed with power saws mounted on a frame with guidance provisions. The joints shall be sealed with an approved polysulfide sealer to a minimum depth of 25 mm (1 in.). Cork, hemp or other compressible material may be used as a backer. The sawcut will not require chamfered edges.

Ends of the parapet shall be formed and the forms securely braced. Parapet sections at light standards, shall be formed for a minimum distance of 1.2 m (4 ft) on each side of the exception.

Equipment or methods which result in dimensions outside the tolerance limits shall not be used. Parapets having dimensions outside the tolerance limits will be rejected and shall be removed and replaced. The maximum variance of actual to proposed longitudinal alignment shall not exceed +20 mm (3/4 in.) with no more than 6 mm in 3 m (1/4 in. in 10 ft). Notwithstanding this tolerance, abrupt variance in actual alignment of 13 mm in 3 m (1/2 in. in 10 ft) will be cause for rejection of the parapet.

In addition, all surfaces shall be checked with a 3 m (10 ft) straight edge furnished and used by the Contractor as the concrete is extruded from the slipform. Parapets having surface irregularities greater than 6 mm in 3 m (1/4 in. in 10 ft) shall be corrected immediately at the Contractor's expense. Continued variations in the barrier surface exceeding 6 mm in 3 m (1/4 in. in 10 ft) will not be permitted and remedial action shall immediately be taken to correct the problem.

Any deformations or bulges remaining after the initial set shall be removed by grinding after the concrete has hardened. The vertical surface at the base of the barrier shall be trowelled true after passage of the slipform machine. All holes and honeycomb shall be patched immediately. The entire surface shall receive a light vertical brush finish before final set.

503.18 Waterproofing. When specified, designated surfaces of concrete structures shall be waterproofed by one of the following methods. Surfaces below the ground, which are to be waterproofed, shall be given either one coat of Asphalt Primer: RC-70, and 2 mop coats of Petroleum Asphalt: AWP Type A; or 2 mop coats of Asphalt Emulsion for Waterproofing. Surfaces above the ground line which are to be waterproofed shall be given one coat of Asphalt Primer: RC-70 and 2 mop coats of Petroleum Asphalt: AWP, Type B. With the approval of the Engineer, spraying will be permitted in lieu of mopping.

The surfaces to be waterproofed shall be smooth and free from projections or porous places. The surface shall be cleaned of dust, dirt, grease and loose particles and shall be dry at the time the waterproofing is applied. Petroleum Asphalt

waterproofing shall not be applied until at least 7 days have elapsed after placing of the concrete. Asphalt Emulsion waterproofing may be applied as soon as the forms are removed. No waterproofing shall be done in wet weather, or if local conditions indicate that rain is imminent, or when the temperature of the air in the shade is below 10 ºC (50 ºF), without the written permission of the Engineer, except as specified for Asphalt Emulsion.

When waterproofing with Petroleum Asphalt, the primer shall be applied to the surface of the concrete in a uniform coating and may be applied without heating. The primer shall be applied at least 24 hours before applying the first mopping of hot bitumen. The bitumen for each of the two mop coats shall be heated to a temperature which will permit uniform application. Asphalt shall not be heated above 175 ºC (350 ºF). The amount of bitumen applied in the two moppings shall be approximately 3 L/m^2 (8 gal/100 sq ft) of finished work. If any imperfections appear in the waterproofing, additional coats will be required.

When waterproofing with Asphalt Emulsion, two uniform coats, free from holes or holidays, shall be applied. The second coat shall be applied as soon as the first coat has dried. The minimum total quantity applied in the two coats shall be 1 L/sq mm (3 gal/100 sq ft) When the temperature of air in the shade is below 7 ºC (45 ºF), and the requirements of Article 1020.13(e) have been complied with, Asphalt Emulsion waterproofing may be applied down to a temperature of 0 ºC (32 ºF). Regardless of the temperature during application the material shall be kept at a temperature above 10 ºC (50 ºF). A minimum drying time of 24 hours is required before backfilling, but no backfilling shall commence until the requirements of Article 502.10 are met.

503.19 Protective Coat Application. When specified, a protective surface treatment consisting of 2 coats of boiled linseed oil mixture shall be applied to the entire top surface of the bridge deck, the top surfaces of the sidewalks, the hubguards, and the tops and inside vertical faces of the sidewalk parapets, end posts and wings. The concrete must be at least 14 days old and all saw cut grooving and cleanup operations must be completed before application of the oil mixture.

Application of the protective coat shall be according to the requirements of Article 420.21, except that an air blast shall be directed over the surfaces to be treated immediately before application of the mixture so that all dust will be removed and hand methods of application will be permitted.

503.20 Opening Structures to Traffic. The concrete superstructures shall be opened to traffic according to Article 701.05(d)(1).

503.21 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. All concrete will be measured for payment and the volume computed in cubic meters (cubic yards). In computing the volume of concrete for payment, the dimensions used will be those shown on the plans or ordered in writing by the Engineer. Increased quantities resulting from the use of the slipform option for concrete parapets will not be measured for payment. Deductions will be made for the volume of piling, except for steel

H pile, encased in the concrete. No deduction will be made for the volume of concrete displaced by steel reinforcement, drain holes, floor drains and expansion joint material. The quantity of concrete involved in scoring and chamfers 1300 mm^2 (2 sq in.) or less in cross sectional areas will be neglected in all measurements for payment.

When shown on the plans or ordered in writing by the Engineer, concrete for foundation seals will be measured for payment within the cofferdam sheeting. The vertical dimension used in computing the volume will be the average thickness of the seal between the top of the seal not to exceed the elevation shown on the plans for the bottom of the footing and the bottom of the excavation, but in no case lower than the elevation shown on the plans for the bottom of the foundation seal. The horizontal dimensions used will be the average measurement from center to center of the interlocks of the sheet piling in opposite walls of the cofferdam, but in no case will these dimensions be taken as more than 600 mm (2 ft) beyond the neat lines of the footing in any direction, except that provision may be made for a sump at one end of the cofferdam if necessary.

Preformed elastomeric compression joint seals for bridge expansion joints will be measured for payment in place in meters (feet).

Neoprene expansion joints will be measured for payment in place along the centerline of the joint in meters (feet).

Bridge deck grooving will be measured for payment in place and the area computed in square meters (square yards). In computing the area for payment, no deductions will be made for grooving omissions at deck drains, expansion joints or longitudinal joints or lane lines.

The areas upon which the protective coat has been applied will be measured for payment and computed in square meters (square yards).

Joint fillers, water seals, drain holes, floor drains and welded wire fabric reinforcement, except when specified, will not be measured for payment.

The installing of conduits, sleeves and metal inserts for hangers, the installing or erecting and painting of structural steel that cannot be completely installed or erected prior to the concrete work, and the adjusting of steel members or parts that cannot be finally adjusted prior to the concrete work, will not be measured for payment when the materials for this work are furnished to the Contractor without cost to the Contractor and the contract does not provide for separate payment for this work.

Rubbed finish, when required, will be measured for payment in square meters (square feet) of surface area rubbed.

No measurement or other allowance will be made for work or materials for forms, falsework, shoring, bracing, pumping or other incidentals necessary to complete the work as required.

The quantities of items, other than above, which constitute the completed structure will be measured for payment as specified for the items involved.

503.22 Basis of Payment. Concrete for cast-in-place structures and superstructures will be paid for at the contract unit price per cubic meter (cubic yard) for CONCRETE STRUCTURES and for CONCRETE SUPERSTRUCTURE.

Other cast-in-place concrete for structures will be paid for at the contract unit prices per cubic meter (cubic yard) for CONCRETE HANDRAIL, CONCRETE MASSIVE STRUCTURES and SEAL COAT CONCRETE. When one class of concrete is substituted for another, as provided by Article 503.02, the class of concrete to be paid for will be that specified. When no unit price is provided for Seal Coat Concrete, foundation seals ordered in writing by the Engineer will be paid for according to Article 109.04.

Reinforcement will be measured and paid for according to Section 508.

Expansion bolts, when specified, will be paid for according to Article 540.08.

Rubbed finish will be paid for at the contract unit price per square meter (square foot) for RUBBED FINISH.

Floor drains, other than Frames and Grates, will be paid for at the contract unit price each for FLOOR DRAINS.

Preformed elastomeric compression joint seals for bridge expansion joints shall be paid for at the contract unit price per meter (foot) for PREFORMED JOINT SEAL of the size specified.

Texturing of bridge decks by saw cut grooving will be paid for at the contract unit price per square meter (square yard) for BRIDGE DECK GROOVING, which price shall include all labor, materials, equipment and incidental items necessary to complete the work. The steel expansion dams will be paid for as structural steel according to Section 505.

Neoprene expansion joints will be paid for at the contract unit price per meter (foot) for NEOPRENE EXPANSION JOINT of the expansion range size specified, NEOPRENE EXPANSION JOINT (DAM), or NEOPRENE EXPANSION JOINT (LONGITUDINAL). This price shall be payment in full for anchor bolts, threaded rods, threaded studs, anchor studs, installing hardware, sealant and adhesive, seat preparation, and installation. No additional compensation will be allowed the Contractor for correction of joint seats constructed by the Contractor under other items of work or for correction of loose, long or misaligned anchor bolts.

Items of structural steel, when specified, will be measured and paid for according to Section 505.

Elastomeric bearing assemblies, furnished and installed, including the elastomer, structural steel bearing plates, TFE sheets, stainless steel sheets, and other component parts, as specified, will be paid for at the contract unit price each for ELASTOMERIC BEARING ASSEMBLY of the type designated. Side retainer, anchor bolts, and shim plates will be measured and paid for according to Section 505. When

an Elastomeric Bearing Assembly is requested by the Department for testing, the furnishing and delivering of the additional assembly will be paid for according to Article 109.04.

When the fabrication and erection of elastomeric bearings and other collateral work are accomplished under separate contracts, the applicable requirements of Article 505.09 shall apply.

Fabricated elastomeric bearings and other materials complying with the requirements of this item, furnished and accepted, will be paid for at the contract unit price each for FURNISHING ELASTOMERIC BEARING ASSEMBLY of the type designated.

Storage and care of fabricated elastomeric bearing assemblies by the Fabrication Contractor beyond the specified storage period, will be paid for at the contract unit price per calendar day for STORAGE OF ELASTOMERIC BEARING ASSEMBLIES if a pay item is provided for in the contract, or will be paid for according to Article 109.04 if a pay item is not provided in the contract.

Elastomeric bearing and other materials fabricated under this item erected according to the requirements of the specifications, and accepted, will be paid for at the contract unit price each for ERECTING ELASTOMERIC BEARING ASSEMBLY of the type designated.

Protective coat, when specified, will be paid for at the contract unit price per square meter (square yard) for PROTECTIVE COAT, which price will be payment in full for the 2 applications.

Waterproofing, as specified, will not be paid for separately but shall be considered as included in the unit price bid for the concrete item involved.

Concrete protected according to Article 1020.13(e) may be paid for at the adjusted unit prices which will be the following percentages of the contract unit price for the classes of concrete involved. These adjustments will be made only when they are authorized in writing by the Engineer. No adjustment will be made in the contract unit prices for any concrete if winter work is necessary to meet the required completion dates specified in the contract.

The adjusted unit prices specified for concrete shall be considered as compensation in full for the construction of the concrete, for protection and heating, and for all additional costs incurred because of winter construction. No adjustment will be made in the contract unit price of any other item of work performed according to these requirements.

No adjustment will be made for filling metal shell piles.

UNIT PRICE ADJUSTMENTS	
Type of Construction	Percent Adjustment in Unit Price
For concrete in substructures, culverts (having a waterway opening of more than 1 sq m (10 sq ft), pump houses, and retaining walls (except concrete pilings, footings and seal coats):	
When protected by:	
Protection Method II	115%
Protection Method I	110%
For concrete in superstructures:	
When protected by:	
Protection Method II	123%
Protection Method I	115%
For concrete in footings:	
When protected by:	
Protection Method I, II or III, and slope walls	
Protection Method I or III	107%

SECTION 504. PRECAST CONCRETE STRUCTURES

504.01 Description. This work shall consist of the construction of structures or portions thereof, of precast or precast, prestressed concrete structural members, manufactured and erected as specified.

504.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Preformed Bearing Pads	1082
(b)	Reinforcement Bars	1006.10
(c)	Prestressing Steel	1006.10
(d)	Welded Wire Fabric	1006.10
(e)	Transverse Tie Rods and Dowel Rods	1006.06
(f)	Non-Shrink Grout	1024
(g)	Portland Cement Concrete	1020

504.03 Equipment. Equipment shall meet the requirements of the following Articles of Section 1100 - Equipment:

	Item	Article/Section
(a)	Concrete Mixers	1103.01(a)
(b)	Batching and Weighing Equipment	1103.02
(c)	Water Supply Equipment	1103.11
(d)	Hand Vibrator	1103.17
(e)	Vibrating Screed	1103.17
(f)	Truck Mixer (Note 1)	1103.01(b)

Note 1. A truck mixer may be used providing that it meets the requirements as specified in the Manual for Inspectors of Precast, Prestressed Concrete Products.

Plant equipment for manufacturing the precast concrete units shall meet the approval of the Engineer.

CONSTRUCTION REQUIREMENTS

504.04 General. Precast concrete structural members shall be manufactured in a plant or other location where strict control over the manufacturing procedure is maintained at all times. Plants or other locations manufacturing the members must be approved by the Engineer. Construction requirements shall be according to Section 503, and as specified.

(a) Shop Drawings. The Contractor shall submit shop drawings to the Engineer for approval. Prints of the drawings shall be submitted in duplicate, with a record of any discrepancies and necessary changes in the plans noted. These drawings shall be on sheets 594 mm (24 in.) by 841 mm (36 in.) in size and of adequate quality for microfilming by the Department. All drawings shall be completely titled according to the contract plans and shall pertain to only one structure. Upon approval, the Contractor shall furnish 3 or more prints of the approved drawings, which shall become a part of the original contract and shall be subject to all general or Special Provisions governing it. Changes on approved drawings shall be subject to the approval of the Engineer and a record of all such changes shall be supplied to the Engineer. The Contractor shall be responsible for the accuracy of the drawings even though approved by the Engineer.

(b) Forms. Forms shall meet the requirements of Article 503.06, except as specified for precast, prestressed members.

(c) Reinforcement and Accessories. Reinforcement bars shall meet the requirements of Section 508. The bars shall be rigidly fastened together by wire ties, and extra tie bars shall be furnished as may be necessary for maintaining satisfactory rigidity during handling and placing. Welding will be permitted where approved by the Engineer. Sufficient chairs shall be furnished for supporting the reinforcement at the proper distance from horizontal surfaces. Chairs may also be used as spacers to hold

reinforcement at the proper distance from vertical surfaces. The concrete cover over all reinforcement shall be within ± 5 mm (± 1/4 in.) of the specified cover.

Welded wire fabric shall be accurately bent and tied in place. Welding will be permitted where approved by the Engineer.

Miscellaneous accessories to be cast into the concrete or for forming holes or recesses shall be carefully located and rigidly held in place by bolts, clamps or other effective means. If paper tubes are used for vertical dowel holes, or other vertical holes which require grouting, they shall be removed before transportation to the construction site.

(d) Concrete. The materials shall be combined so as to produce a concrete meeting all the requirements specified in Articles 1020.04 and 1020.05 for Class PC Concrete for precast structures and for Class PS Concrete for precast, prestressed concrete members. It shall be the Contractor's responsibility to determine the proportions of the materials for the concrete, and to exercise quality control with respect to the mixture, so that each batch of concrete entering into the members will meet the requirements specified. Batches of concrete not meeting the requirements as to slump and entrained air content will be rejected.

Before the work begins, the Contractor shall furnish the Engineer a listing of the name, source, brand or type and/or supplier for each of the materials, and shall secure the Engineer's approval of the proportions of cement, fine aggregate, coarse aggregate, admixtures and water the Contractor proposes to use.

504.05 Precast Concrete Members. Bridge slabs, pile caps and other precast concrete structural members, which may be specified, shall conform to the following specific requirements. All reinforcement bars, tie bolts, anchor dowels, bearing pads, inserts, grout and mortar required for the manufacture and erection of the units shall be included.

(a) Manufacturing. The Contractor shall make, cure and test the concrete test specimens as directed by the Engineer. A minimum of four test specimens of concrete shall be made for each seven units, or a minimum of four specimens per day shall be made if less than seven units are constructed. Test specimens shall be 150 mm (6 in.) diameter by 300 mm (12 in.) cylinders.

The roadway surface of bridge slabs shall be finished with a wood float and the exposed face and top of curb section shall be finished according to Article 503.16(a).

Side forms may be removed when, by so doing, no distortion, slump or misalignment of the concrete will be caused.

Curing shall be as specified in Article 1020.13, and shall be continued until the concrete has attained a compressive strength as specified on the plans but not less than 30,000 kPa (4500 psi). Steam curing will also be

permitted, provided that the method and its details meet the approval of the Engineer.

The units shall remain on the bottom supporting forms until the concrete has attained a compressive strength of not less than 14,000 kPa (2000 psi). The curing may then be interrupted while the units are being moved to a storage area for further curing. All test specimens shall remain with the units and shall be subjected to the same curing as the units until the time of testing.

When the concrete has attained a compressive strength as specified on the plans but not less than 30000 kPa (4500 psi), and not prior to four days after casting, the units may be loaded, shipped and used.

Only those members bearing identification marks of acceptance by the Department will be permitted for use in the construction.

The number of test specimens available should be sufficient for determining the specified concrete strengths accurately. If the supply of test cylinders becomes exhausted, cores for additional tests shall be taken from the units as directed by the Engineer.

(b) Tolerance of Dimensions. The four sides of the members shall not vary more than 3 mm (1/8 in.) for the full depth of the member when tested with a straightedge in a vertical direction, nor more than 5 mm (1/4 in.) in the full length of the member when tested with a straightedge in a horizontal direction; nor shall the surface of the member deviate more than 3 mm (1/8 in.) from a straight line 3 m (10 ft) long connecting two points on the member's surface.

(c) Handling and Placing. The members shall be handled in a manner that will not cause crushing, spalling or undue marring of the concrete.

The ends of precast members shall not be permitted to extend a distance exceeding the depth of the member on any vehicle, bolster or other point of bearing during hauling or stockpiling.

Precast members shall be handled with a suitable hoisting device or crane provided with a spreader sling of sufficient capacity to handle the members. The spreader shall be of sufficient length to prevent horizontal forces in the member due to lifting, and shall be equipped with leads and hooks at each end. For the purpose of engaging the threaded inserts provided in the member, the manufacturer shall provide a sufficient number of eye bolts of proper size.

Before lifting the member, all lifting inserts in each end shall be fully engaged with the spreader lead hooks. In the event that raising by alternate lifting and blocking of opposite ends is performed, the lifted end shall not be rotated unless a proper pivoting device for the opposite end has been provided.

Erection of precast bridge slabs shall commence at the centerline and proceed, one slab at a time, working out to the curb. As each slab is placed,

the transverse tie bars shall be inserted and secured. Any shifting of the beams must be done while they are held free of the supports by the hoisting device or crane. The use of a steel pinch bar will not be permitted.

The abutting edges of each unit shall be carefully cleaned of any concrete or extraneous matter in order that the longitudinal joints can be bolted tightly together.

Care shall be exercised to keep bridge seats free of foreign material when placing the slabs. After the units have been placed and fastened together and the end anchor dowels are placed, the longitudinal joints between the units shall be filled with a very dry mix mortar consisting of one part cement, one part sand, and water; the amount of water to be determined by the Engineer. The mortar shall be cured for a period of not less than 3 days by the wetted burlap method according to Article 1020.13 (a)(3). Curing shall commence as soon as practicable after mortar placement joints shall be filled.

Pile caps shall be carefully lowered into their proper position over the piles and to the specified elevation. After the units have been placed, the recess holes shall be filled with a dry mix mortar consisting of one part cement, one part sand, one and one-half parts chips or pea gravel, and water; the amount of water to be determined by the Engineer. To ensure that the recess holes are completely filled, the mortar shall be vibrated into place.

504.06 Precast, Prestressed Concrete Members. Deck beams, I-beams, Bulb T-beams, and other prestressed concrete structural members which are specified shall conform to the following specific requirements. All reinforcement bars, inserts and accessories cast in the members, and all tie assemblies, threaded rods, anchor dowels, bearing pads and shims, joint material, mortar, grout, and other materials necessary and required for the manufacture and erection of the members shall be included.

The Manual for Inspectors of Precast, Prestressed Concrete Products in effect on the date of invitation for bids, setting forth policies adopted by the Department that have been observed to produce satisfactory results, shall govern with respect to details of procedure, except that modifications that have been shown to produce equally satisfactory or superior results may be approved. This Manual is available without charge, upon request, from the Engineer.

Shop drawings will be required according to the requirements of Article 504.04(a).

(a) Prestressing Steel. Each reel of the prestressing steel shall be identified by the reel number. Strands from more than one source shall not be used in any one tensioning operation. The Contractor shall furnish to the Engineer a test sample 2 m (7 ft) in length from each coil or reel. The test sample shall be cut with a torch in a manner that will weld or fuse together the ends of the individual wires of the strand. Samples shall be identified by reel number. They shall not be coiled for shipment to the laboratory for testing.

All prestressing strands shall be free of dirt, oil, paint, corrosion or any foreign material that may prevent bond between the strands and the concrete. The use of prestressing strands having kinks, bends, nicks or other defects will not be permitted.

(b) Lifting Devices and Void Tubes. Lifting devices shall be fabricated and anchored or tied in place, as shown on the plans. Other types may be used upon written request by the Contractor and with written approval of the Engineer.

Unless otherwise provided, all deck beams shall have void tube drains and air vents. The forming of the drains and vents, their location and the material used for the forming shall be approved by the Engineer. When no longer needed, the air vents shall be filled as directed by the Engineer.

Void tubes or inside forms shall be as shown on the plans and approved by the Engineer. They shall be composed of materials and of a design that will enable them to withstand the forces imposed upon them during the fabrication of the deck beams without substantial deformation such as bulging, sagging or collapsing. It is the Contractor's responsibility to fabricate a void that meets the requirements of the plans. Contractors who have not previously manufactured members with void tubes, or who are using a type of void tube or void tube materials not previously used or proven satisfactory, will be required to construct a test section of the member, not less than 3 m (10 ft) in length, so the placement and behavior of the tube may be observed by the Engineer prior to approval. Void tubes shall be protected against damage during storing and handling. Damaged void tubes shall not be used.

(c) Manufacturing. The members shall be pretensioned. The adequacy and suitability of the equipment used to perform the work shall be subject to review by the Engineer. All phases concerning the method of pretensioning, use of hydraulic jacks and gages, cutting strands, curing, plant handling, transporting and other operations necessary and incidental to the construction and delivery of members, shall be subject to approval of the Engineer.

(1) Prestressing Equipment and Operation. Hydraulic jacks, screw jacks or other approved equipment shall be used for tensioning the strands. The tensioning system shall be equipped with gages or other indicating devices for accurate determination of the loads applied to the strands. All devices shall be calibrated by a laboratory approved by the Engineer and a certified calibration curve shall accompany each. Recalibration shall be made when directed by the Engineer, and the Engineer reserves the right to check the calibration at any time to assure the stress in the prestressing steel can be accurately computed at all times. Hydraulic pressure gages shall have a full pressure capacity of approximately twice the normal working pressure. A separate approved system of applying and measuring pre-loads shall be employed when more than one strand is to be tensioned in the same operation.

All tensioning of strands shall be performed in the presence of the Engineer, and a record shall be kept of the jacking force and the strand elongation produced. No tensioning of strands will be permitted at temperatures below -12 ºC (10 ºF). Several members may be cast in one continuous line, provided that all members are fabricated without undue intervening delay. When the temperature at the time of tensioning is such that correction must be made to compensate for change in strand stresses, all members on the bed shall be cast in a continuous pour; otherwise, the time intervening between the casting of the first and last member on the bed shall not exceed 4 days. The Contractor shall take effective safety measures to prevent injuries of personnel due to breakage of strands or failure of anchorage devices during tensioning operations.

After completion of the tensioning, anchorage devices for holding the stressed strands shall permit no slippage, and the strands shall be held in the proper position on the bed within a tolerance of ± 5 mm (± 1/4 in.). Sag of the bottom row of strands shall be eliminated by the use of wire chairs having plastic coated tips or plastic chairs.

The following tabulation shows the total prestressing loads to which individual strands of various sizes shall be tensioned:

*Fu = 1860 kPa			
Nominal Diameter, mm	Nominal Steel Area, Sq. mm	Total Prestressing Load, N	
		Stress Relieved	Low-Relaxation
9.53	54.84	71400	76500
11.11	74.19	96600	103500
12.70	98.71	128500	137700

*Fu = 270 KSI (Grade 270)			
Nominal Diameter, In.	Nominal Steel Area, Sq In.	Total Prestressing Load, Lb	
		Stress Relieved	Low-Relaxation
3/8	0.085	16,000	17,200
7/16	0.115	21,700	23,200
1/2	0.153	28,900	30,900

*Fu = Minimum specified ultimate tensile strength.

The prestressing strands shall be accurately placed and held in position on the casting bed, anchored at the fixed end and stressed to the required tension. Regardless of the method used, each strand individually shall be initially tensioned to a pre-load of 9 kN (2000 lb), unless otherwise directed by the Engineer, and a mark against which to

measure elongation under subsequent loading shall be placed on the strand. The gage and elongation measurements for subsequent loadings shall include allowances for slippage and thermal expansion of the strands.

When the strands are to be tensioned individually, the load on each shall then be increased to the required amount as indicated by the gage, and the accuracy of the increase shall be checked by measurement of the elongation of the strand, and the load so determined shall equal that indicated by the gage within three percent of the required load.

If two or more strands are to be tensioned simultaneously by the same jack, the load shall be increased until the final load on each strand is attained, as indicated by measurements of the elongation of the strands, and the combined load on the strands so determined shall equal that shown on the gage within three percent of the required load. The Contractor shall furnish and have available at least two load cells of approved design, which shall be placed on strands on opposite sides of the line of pull, as designated by the Engineer, for further verification of the accuracy of the load and for checking the uniformity of pull on individual strands.

When deflected strands are required, these shall be held in proper position with respect to the soffit plate by suitable anchoring devices that will cause a minimum of friction during tensioning. Each deflected strand shall be pre-loaded and individually tensioned to the full load, as described above, and the load as determined from the strand elongation shall check that indicated by the gage within five percent of the total load required. If a less satisfactory check is obtained, the strand shall be tensioned from both ends of the casting bed and the load as calculated from the sum of the strand elongations shall check that indicated by the gage within five percent of the total load required.

The prestressing force shall be transferred to the concrete only after it has attained the specified age and strength, and only with the approval of the Engineer. The release of the strands shall be accomplished in a manner that will create a minimum of eccentric force acting upon the beam. Unless the method suggested in the Manual for Inspectors of Precast, Prestressed Concrete Products is followed, and in any case where draped strands are involved, the Contractor shall submit for the approval of the Engineer the pattern the Contractor proposes to use in releasing the strands. Except when the ends are to be encased in concrete, the prestressing strands shall be trimmed within 3 mm (1/8 in.) of the concrete and the ends of the members shall be given two coats of an asphalt paint. The release of the strands shall be accomplished as soon as the required strength and age have been attained, and while the concrete is still warm if steam curing is used.

(2) Forms. Exterior forms shall be steel. Inside forms or void tubes for deck beams may be of treated cardboard, plywood or other suitable materials.

The casting bed shall have a concrete deck to which the form grillage and soffit plates shall be adequately anchored. Soffit plates shall be accurately centered, aligned and leveled to the same plane.

Side forms shall have form plates of sufficient thickness, shall be sufficiently braced, and shall be anchored so as to withstand the forces due to vibratory placement of the concrete and to maintain correct alignment. The ends or sides of adjacent sections of form which are butt-joined shall match smoothly and tightly and shall result in proper alignment. The side forms shall be cross tied above the finished surface of the member at sufficiently close spacing to maintain true cross sectional dimensions. Side forms for deck beams shall be provided with test holes at sufficiently close spacing for checking the wall thickness of the beams during the construction operations.

The design of bulkheads shall be such that they can be placed and maintained in correct position between the side forms. Clamps, bolts or other devices connecting the bulkheads to the side forms shall be capable of being removed or loosened before steam curing is applied, so that expansion of the side forms may occur freely and without damage to the beams. The bulkheads shall have slots or holes, conforming to the strand pattern, to permit passage of the prestressing strands. Sufficient space shall be left between bulkheads to properly permit the operations necessary for releasing the strands.

In the case of deck beams, provision shall be made for holding the inside forms or void tubes accurately in place to prevent flotation and misalignment.

All exposed outside edges shall be beveled or chamfered as shown. Leakage of mortar will not be permitted. Joints between soffit, side forms and bulkheads shall be tight and, if necessary, shall be gasketed with rubber which may also be used to provide the corner chamfers. Plugging of holes and slots in the forms shall be neatly done so that the finished members shall have a professional appearance. Before the concreting operations begin, the forms and casting bed shall be treated with a suitable form oil or other approved material to prevent bonding of the concrete. Extreme care shall be exercised to prevent the coating of prestressing strands and reinforcement bars with such material, and any strands or bars so contaminated shall be satisfactorily cleaned or replaced. After forms are removed, and prior to transporting deck beams, all form oil or other form release material residue shall be removed from the keyway surfaces by sandblasting.

Forms shall be free from paint or other protective substance that may cling to the surface of the members. Forms not thoroughly cleaned after prior use shall not be used.

If during the casting it becomes apparent that forms have deteriorated to the degree that members no longer can be constructed without approaching or exceeding the dimensional tolerance limits, the

Engineer may order production suspended with respect to the use of the unsatisfactory forms until they have been completely renovated or replaced.

(3) Testing of Concrete. The Contractor shall furnish, and have available for use of the Engineer, approved equipment for slump and air content determinations, and sufficient molds for making the specified number of cylindrical test specimens.

Tests of the concrete mixture for air content and slump will be performed after delivery to the casting site and before the concrete is incorporated into the members. The slump of the concrete shall be no greater than is necessary for proper placement and consolidation. The policies adopted by the Department as set forth in the Manual for Inspectors of Precast, Prestressed Concrete Products will govern for slump.

A minimum of 6 test cylinders shall be made from the concrete mixture per casting bed. The cylinders shall be cast from samples taken from batches designated by the Engineer after delivery to the casting site, and as the concrete mixture is being discharged for incorporation into the member.

The cylinders shall be placed with and cured in the same manner as the member. The position of the cylinders during curing shall be such that no undue advantage is given to them, as compared to any part of the member, with respect to environment favorable to gain in strength. The cylinders shall remain with the member until removed for testing or until the prestress forces are transferred to the concrete in the member. The cylinders reserved for the 28 day tests shall be cured at the same location, and in exactly the same manner, length of time and under the same atmospheric conditions as the members they represent. The Contractor shall furnish an approved testing machine and shall perform the testing of the cylinders, but the tests shall be performed only in the presence of the Engineer. The Engineer reserves the right to check the accuracy of the testing machine prior to or at any time during the period of performing the tests.

(4) Placing and Consolidating.The forms, prestressing steel, reinforcement and accessories shall be inspected and approved by the Engineer immediately prior to placing the concrete, and no concrete shall be placed until such inspection has been made, but such approval shall not relieve the Contractor of responsibility as to the results obtained. Concrete shall be placed in horizontal lifts and consolidated by internal vibration. Internal vibrators shall have a vibrating head not more than 30 mm (1 1/4 in.) in diameter. At locations of relative massive concrete and away from the prestressing strands, where, with the exercise of ordinary care, the reinforcing steel will not be displaced, the Engineer may approve the use of larger vibrators. External vibration may be used in conjunction with the internal vibration, if approved by the Engineer. Vibration shall be performed with care to avoid the

displacement of reinforcement, prestressing steel, and accessories, and to ensure satisfactory consolidation.

In the case of deck beams, the bottom slab shall be placed, consolidated with vibratory equipment and screeded or tamped to the proper thickness before the inside forms or void tubes and the top bar reinforcement is placed. Workers will not be permitted to walk on top of the inside forms, and concrete will not be permitted to accumulate excessively on them during the period of placing the mixture between the outside and inside forms. In the case of members utilizing cylindrical void tubes, the Engineer may approve the placing of the void tubes, and the positioning of the reinforcement before concrete operations begin, provided that it can be assured that the void tubes will be correctly located in the finished member. Fabric reinforcement when used shall be placed as shown on the plans before the side forms are set.

The concreting operations shall proceed at a rate sufficient to ensure that no seams or cold joints shall exist. Vibration of each lift shall be sufficient to eliminate honeycomb and excess water and air pockets, and the vibrators shall be inserted completely through the lift and barely into the preceding lift to ensure proper unification at the junctures of all lifts. The vibrator shall be inserted and removed slowly but will not be permitted to remain stationary in the concrete and shall not be forced between strands.

(5) Finishing. The top surface of deck beams shall be screeded with a straightedge and then finished with a wooden hand float. The top surface of I-beams and Bulb T-beams shall be finished initially with a wooden hand float. Further finishing shall be delayed until the water sheen appears, but not to the point of rendering further manipulation ineffective. The surface then shall be roughened with a suitable stiff-bristled broom or wire brush drawn in transverse direction removing any laitance present and breaking up the water sheen. The corrugations formed shall be uniform in appearance and in no case more than 5 mm (1/4 in.) in depth. Surfaces that will be exposed to view in the completed structure shall be finished according to Article 503.16.

(6) Curing. Members shall be kept wet during the entire period of curing. This may be accomplished by the method specified in Article 1020.13(d) or by steam curing as specified herein or by other methods approved by the Engineer.

Air vents shall be in place, and shall be so arranged that no water can enter the void tubes during the curing of the members. Bolts, clamps or other devices for holding bulkheads, recess blocks and inserts in place during casting shall be removed or loosened to permit free expansion of the forms, without damage to the members, when steam curing is used.

As soon as each member is finished, it shall be covered with not less than 2 layers of wet burlap or other material approved by the Engineer, and placed in contact with the exposed surface. A preset period shall

be determined before the steam is applied. A preset period of less than 4 hours is permitted if determined according to ASTM Designation C 403, except that 1/2 hour shall be added to the determined time. The use of a hand penetrometer is permissible. When the ambient temperature is below 10 ºC (50 ºF), steam shall also be applied during the preset period, but only at a rate sufficient to keep the air surrounding the beam at a temperature between 10 ºC and 20 ºC (50 ºF and 70 ºF).

Steam shall be applied from pipes with perforations at suitable intervals laid along each side of the member, or by other approved arrangement. Jets of steam will not be permitted to impinge directly against the member, or form, or test specimens. Provisions shall be made for effective circulation of the steam around and over the top of the members, by frames at suitable intervals, extending at least 100 mm (4 in.) over the sides of the form, or other approved arrangement, and draping over them a suitable covering, providing a complete closure around the member and steam pipes.

Steam shall be applied in a manner that shall not increase the temperature of the air surrounding the members faster than 4 ºC (40 ºF) per hour. The curing temperature shall be reasonably uniform around each member and shall not exceed 70 ºC (160 ºF). When the steam curing is discontinued, the decrease in the temperature within the closure shall be at a rate not exceeding 4ºC (40 ºF) per hour.

The Contractor shall furnish and have available for the use of the Engineer a minimum of two portable recording thermometers, but not less than one for each 45 m (150 ft) of closure, for use in determining the magnitude and degree of uniformity of temperatures within the closure.

The steam curing shall create a moist, humid condition under the closure, and there shall be no evidence of dehydration of the concrete. Perceptible drying of the wet burlap initially placed on the members will be considered as indicating that the steam curing does not supply sufficient moisture, and a soaker hose placed on top of the members shall be used to augment the steam curing, or other approved corrective measures shall be taken. Forms shall not be removed during the steam curing, except as approved by the Engineer and by a procedure approved by the Engineer. If the forms are removed, wet burlap shall be draped over the sides and ends of the member and the steam curing resumed immediately.

The prestressing force shall not be transferred to any member before the concrete has attained the compressive strength of 28,000 kPa (4000 psi) or other higher compressive strength specified on the plans, as determined from tests of 150 mm (6 in.) by 300 mm (12 in.) cylinders cured with the member and representative of the concrete used in it. Further curing of the member after detensioning is at the option of the producer. However, members cannot be shipped until 28-day strengths have been attained and members have a yard age of at least 4 days.

(7) Weather Precautions. Concrete shall not be placed at outdoor plants during inclement weather. If the concreting operations are in progress when the adverse weather conditions occur, protective covering shall immediately be placed over all exposed concrete. If necessary, the completion of a member in the process of manufacture will be permitted, provided that substantial increase in the water-cement ratio, because of rain, will not occur. Such member will be accepted only if it meets the requirements of the Specifications.

Concrete shall not be placed at ambient temperatures below freezing, unless there exists adequate assurance that the organization of the work and the facilities available are such that the work will be completed and steam applied before damage to the concrete occurs. The casting bed and forms shall be preheated with steam but no water shall remain on the bed, and the concrete shall be delivered at the forms at a temperature not less than 10 ºC (50 ºF) nor more than 32 ºC (90 ºF). Concreting operations shall not start when the ambient temperature is below -4 ºC (25 ºF) and the Engineer may suspend the work at the completion of any one member if there is danger of damage to the concrete.

(d) Inspection of Completed Members. The completed members will be inspected after release of the strands and while they are still on the casting beds or in a holding area, to determine their acceptability under the specification requirements, as of that date. They will be inspected again just prior to shipment, after arrival on the construction site, and after placement in the structure for possible damage during handling, storing, transporting and erecting.

All inspection of completed members will be performed according to the provisions contained in the Manual for Inspectors of Precast, Prestressed Concrete Products.

The Engineer will determine the kind, type and extent of cracks and surface defects such as honeycomb and chipped edges or corners that will be tolerated. All such cracks and surface defects shall be repaired as specified in the Manual for Inspectors of Precast, Prestressed Concrete Products. Members shall be cast without cracks or other defects and true to the dimensions shown on the plans. It is recognized that certain cracks and surface defects may not be detrimental from the standpoint of structural integrity and may be relatively harmless if remedied by proper repair, and that deviations in dimensions from those shown on the plans, within certain limits, can be tolerated.

Maximum dimensional tolerances are listed below and illustrated by sketches in the Manual for Inspectors of Precast, Prestressed Concrete Products. The dimensions of all members shall be well within these tolerances and the maximum values will be permitted to be approached or equaled only occasionally. Equipment and methods which permit an undue proportion of dimensions approaching the tolerance limits shall not be used. Members having dimensions outside the tolerance limits will be rejected.

In the case of deck beams, it is recognized that the beams individually may comply with the tolerances stated below and still not place satisfactorily in the structure. Final acceptance of the beams, therefore, will be conditioned upon satisfactory placement.

Maximum Allowable Dimensional Tolerances For
Precast, Prestressed Concrete Deck Beams

(mm)

Depth, top slab	± 12
Depth, bottom slab	0 to + 12
Depth, overall	± 5
Depth (overall from the bottom of the beam to the top of the angle when angles are required)	± 3
Width, web	± 5
Width, overall	± 5
Length	±3 mm per 3 m, Max. + 15 mm to - 20 mm
Square Ends (deviation from square)	± 5
Skew Ends (deviation from tangent offset)	
Acute angles equal to or less than 30°	± 5
Acute angles greater than 30°	± 12
Beam Seat Bearing Area (variation from plane surface when tested with a straightedge)	± 2
Horizontal Alignment (deviation from a straight line parallel to the centerline of beam)	±3 mm per 4.5 m, Max. ± 15
Dowel Tubes (spacing between the centers of tube and from the centers of tubes to the ends and sides of the beams)	± 12
Tie Rod Tubes (spacing from the centers of tubes to the ends of the beams)	± 12
Tie Rod Tubes (spacing from centers of tubes to the bottom of the beams)	± 12
Total Width of Deck Theoretical width	+ 15 per joint
Maximum Distance Between Beams Measured Below the Keyway	20
Transverse Joints (deviation from specified width)	
Expansion Joints	- 5 to + 15
Fixed Joints	0 to + 15

Maximum Allowable Dimensional Tolerances For
Precast, Prestressed Concrete Deck Beams
(English)

	In.
Depth, top slab	± 1/2
Depth, bottom slab	0 to + 1/2
Depth, overall	± 1/4
Depth (overall from the bottom of the beam to the top of the angle when angles are required)	± 1/8
Width, web	± 1/4
Width, overall	± 1/4
Length	± 1/8 per 10', Max. + 1/2 to - 3/4
Square Ends (deviation from square)	± 1/4
Skew Ends (deviation from tangent offset)	
Acute angles equal to or less than 30°	± 1/4
Acute angles greater than 30°	± 1/2
Beam Seat Bearing Area (variation from plane surface when tested with a straightedge)	± 1/16
Horizontal Alignment (deviation from a straight line parallel to the centerline of beam)	± 1/8 per 15', Max. ± 5/8
Dowel Tubes (spacing between the centers of tube and from the centers of tubes to the ends and sides of the beams)	± 1/2
Tie Rod Tubes (spacing from the centers of tubes to the ends of the beams)	± 1/2
Tie Rod Tubes (spacing from centers of tubes to the bottom of the beams)	± 1/2
Total Width of Deck	Theoretical width + 1/2 per joint
Maximum Distance Between Beams Measured Below the Keyway	3/4
Transverse Joints (deviation from specified width)	
Expansion Joints	- 1/4 to + 1/2
Fixed Joints	0 to + 1/2

Maximum Allowable Dimensional Tolerances For
Precast, Prestressed Concrete I-Beams
and Bulb T-Beams

mm

Depth (flanges, web and fillets)	± 5
Depth (overall)	+ 5 to - 3
Width (flanges and fillets)	± 5
Width (web)	+ 5 to - 3
Length	± 3 per 3 m, Max. + 15 to - 20
Square Ends (deviation from square)	± 5
Skew Ends (deviation from tangent offset)	± 5
Side Insert (spacing between centers of inserts and from the centers of inserts to the ends of the beams)	± 15
Bearing Plates (spacing between the centers of bearing plates)	±15
Bearing Plate (spacing between the centers of bearing plates to the ends of the beams)	± 5
Bearing Plate or Bearing Area (variation from a true horizontal plane or from a plane surface when tested with a straightedge)	± 2
Stirrup Bars (extension above top of the beam)	0 to - 10
Stirrup Bars (longitudinal spacing, provided that there are not less than the required number in a given length)	± 25
End Stirrup Bars - not more than 50 mm from the end of the beam	
Horizontal Alignment (deviation from a straight line parallel to the centerline of the beam)	± 3 per 3 m, Max. ± 30

Maximum Allowable Dimensional Tolerances For
Precast, Prestressed Concrete I-Beams
and Bulb T-Beams
(English)

	In.
Depth (flanges, web and fillets)	± 1/4
Depth (overall)	+ 1/4 to - 1/8
Width (flanges and fillets)	± 1/4
Width (web)	+ 1/4 to - 1/8
Length	+ 1/8 per 10', Max. + 1/2 to - 3/4
Square Ends (deviation from square)	± 1/4
Skew Ends (deviation from tangent offset)	± 1/4
Side Insert (spacing between centers of inserts and from the centers of inserts to the ends of the beams)	± 1/2
Bearing Plates (spacing between the centers of bearing plates)	± 1/2
Bearing Plate (spacing between the centers of bearing plates to the ends of the beams)	± 1/4
Bearing Plate or Bearing Area (variation from a true horizontal plane or from a plane surface when tested with a straightedge)	± 1/16
Stirrup Bars (extension above top of the beam)	0 to - 3/8
Stirrup Bars (longitudinal spacing, provided that there are not less than the required number in a given length)	± 1
End Stirrup Bars - not more than 2" from the end of the beam	
Horizontal Alignment (deviation from a straight line parallel to the centerline of the beam)	± 1/8 per 10', Max. ± 1 1/4

(e) Handling, Storing, Transporting, and Erecting. The handling of precast, prestressed concrete members, from the time of releasing the strands until they are in place in the structure, shall be according to the basic rules specified. Failure to observe these rules may result in damage or destruction of members by the internal stresses. Any member damaged during handling, storing, transporting or erecting shall be replaced by the Contractor at his/her own expense.

The members shall be maintained in upright position at all times and shall be supported only at the ends. During lifting, they shall be supported only by the inserts provided for that purpose. In storage, members shall be supported only at the ends and as specified in the Manual for Inspectors of Precast, Prestressed Concrete Products. During transportation, the ends of I-beams shall not extend a distance of more than the depth of the beam and, in no case, more than 1 m (3 1/2 ft) beyond the bolsters or other supports on the transporting vehicle. The ends of deck beams shall not extend a distance of more than 1 1/2 times their depth, and in no case more than 1 m (3 ft), beyond the supports.

During storage, the supports shall maintain the members in essentially a level position and without twisting. Stacking of members in storage will be permitted only with the approval of the Engineer. If such permission is granted, the supports of all members shall be in the same vertical planes and shall be of adequate thickness to prevent damage to the lifting devices.

Each member shall have proper identification as to number, position in the structure and date of casting painted on its top and on one end. Members shall not be shipped to the jobsite before the 28 day compressive strength data are available except as otherwise specified or approved by the Engineer.

In erecting beams, care shall be taken to keep bridge seats and tops of bearing devices free of foreign materials. Any shifting of beams shall be done while they are held free of the foundation.

Erection of deck beams shall begin at the expansion end or as designated by the Engineer and shall proceed, one beam at a time, across the roadway. During the initial placement of the beams, every effort shall be made by the Contractor to achieve optimum match between beams. The Contractor will be required to shift or interchange beams to achieve a better fit when directed by the Engineer. As the beams are placed in their final position, and prior to securing transverse ties and drilling and grouting dowels, the beams shall be brought to firm even bearing on the seats through the use of the bearing pads and fabric shims furnished with the beams, and/or grinding of the concrete seats as required.

After deck beams are properly placed and firm even bearing assured, the beams, either in pairs for skewed structures or all beams for right angle structures, shall be secured in lateral position by placing and tightening of the transverse tie assemblies. Dowels at the fixed ends of the deck beams shall then be drilled and grout placed and cured and the cast-in- place concrete at the expansion end of the deck beams placed and cured. After this work is completed, the longitudinal keyways between beams shall be filled with an approved non-shrink grout. Prior to grouting, all openings between beam edges at the base of the longitudinal keyways shall be caulked or sealed with a suitable compressible material to prevent leakage of grout. Prior to placement of the grout, the keyways shall be clean and free of all oil, grease, laitance and other foreign substances. The grout shall be mixed and placed according to the grout manufacturer's written instructions or specifications except the use of aggregate in the grout will not be permitted. The minimum grout temperature at the time of placement shall be 10 ºC (50 ºF). Rotating drum type concrete mixers will not be allowed for mixing the grout. The keyway surfaces shall be soaked with water for one to two hours prior to placement of grout. During placement of the grout, the grout mixture shall be worked into the keyway with the trowel blade or with a pencil vibrator. The surface shall be troweled to a smooth finish. The grout shall be cured with wet burlap for a minimum of three days. This grout also shall be used for grouting the dowels. The Contractor, at his option, also may use this non-shrink grout for grouting between the ends of the deck beams at fixed piers and for the transverse tie assembly pockets. During the curing period, no vehicular traffic, including the Contractor's

equipment, will be permitted on the beams. In stage construction with deck beams, stage one shall be constructed as a complete deck. The transverse ties for stage one construction shall not be released during construction of stage two. Threaded sleeves shall be used to secure stage two deck beams to stage one deck and at no time shall the transverse tie nuts for stage one be loosened or removed.

The keyway grout and grout at fixed ends of deck beams will be inspected by the Engineer for cracks. Any cracks found other than shrinkage cracks along the keyway edges shall be sealed at the Contractor's expense with an epoxy bonding compound according to Article 1025.03. The bonding compound shall be applied into the cracks until the cracks are full. The bonding compound shall be a product specifically recommended by the manufacturer, in their printed specifications, for grouting non-moving damp cracks in concrete.

If the cracks are propagating along the keyway from the end of beams, it could indicate the beam or beams are not firmly seated. If this is the case, the Contractor prior to sealing shall check for beam wobble and shim any beams not firmly seated.

504.07 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Precast concrete bridge slabs and precast, prestressed concrete deck beams will be measured by the square meter (square foot) of horizontal surface area of the individual slabs or beams, as shown on the plans. In determining the total number of square meters (square feet) to be paid for, the overall horizontal surface area of all the slabs or beams specified will be used.

Precast, prestressed concrete I-beams, or Bulb T-beams will be measured by the meter (foot). In determining the total length of beams to be paid for, the specified overall length of the individual beams will be used.

Precast concrete pile caps will be measured for payment in place as each precast concrete cap.

Precast concrete structural members, not specifically mentioned or covered herein, will be measured and paid for as specified in other sections of these specifications, on the plans, or in the Special Provisions.

504.08 Basis of Payment. This work will be paid for at the contract unit price per square meter (square foot) for PRECAST CONCRETE BRIDGE SLAB and PRECAST, PRESTRESSED CONCRETE DECK BEAMS of the depth specified, or per meter (foot) for FURNISHING AND ERECTING PRECAST, PRESTRESSED CONCRETE I-BEAMS, or BULB T-BEAMS of the depth specified.

Precast concrete pile caps will be measured and paid for at the contract unit price each for PRECAST CONCRETE CAPS.

SECTION 505. STEEL STRUCTURES

505.01 Description. This section shall apply to structures or portions of structures built of structural steel shapes and plates, steel and iron castings, steel forgings, wrought iron and miscellaneous metals.

The work included under this item shall consist of furnishing, fabricating, transporting, erecting, and painting the materials described above, except when limited to only certain portions of the work by the terms of the contract.

505.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 – Materials:

	Item	Article/Section
(a)	Structural Steel	1006.04
(b)	Turned and Ribbed Bolts	1006.07
(c)	High-Strength Steel Bolts, Nuts and Washers	1006.08
(d)	Anchor Bolts	1006.09
(e)	Steel Forgings	1006.12
(f)	Steel Castings	1006.13
(g)	Gray Iron Castings	1006.14
(h)	Malleable Castings	1006.16
(i)	Cast Bronze Plates	1006.21
(j)	Rolled Copper-Alloy Plates	1006.22
(k)	Paint Materials and Mixed Paints	1008.01 - 1008.23
(l)	Stud Shear Connectors	1006.32

Materials for structures that will carry railroad traffic shall satisfy AREMA Specifications.

505.03 Drawings. Before steel fabrication begins, the Contractor shall submit duplicate prints of shop drawings to the Engineer for review and preliminary approval. These drawings shall be on full size sheets (594 mm (24 in.) by 841 mm (36 in.)) or reduced size sheets(279 mm (11 in.) by 432 mm (17 in.)). Each full or reduced size sheet shall provide adequate space for review and approval stamps at the lower right corner, and both lettering and details must insure legibility for review and reproduction after microfilming. Each drawing shall be completely titled according to the contract plans, including structure number, state contract number, route, section, and county, and shall pertain to only one structure. If the submitted shop drawings have significant discrepancies, revised sets must be submitted until details comply with the contract requirements. After all review comments have been addressed and preliminary approval is given, the Contractor shall furnish six or more full or reduced sized prints of the drawings as directed by the Engineer, and these shall be distributed and become a part of the contract. Changes to previously approved shop drawings shall be subject to the approval of the Engineer, and the Engineer shall be supplied with a record of all such changes. The Contractor shall be responsible for the shop drawings satisfying contract requirements, regardless of any approval by the Engineer.

After the Engineer's preliminary approval and prior to distribution, prints of shop drawings for structures that will carry railroad traffic shall also be submitted for the approval of the Railroad Engineer. Upon request, the Contractor shall also furnish full size reproducibles, 594mm (24 in.) by 841 mm (36 in.), including margins. The margin at the left end shall be 40 mm (1 1/2 in.) and the others 13 mm (1/2 in.) wide. These reproducibles shall become the property of, and shall be delivered to, the Railroad upon completion of the contract.

During the preparation of shop drawings, the Contractor shall check all general dimensions of the steel work and shall report any discrepancies discovered to the Engineer for revision and correction before fabrication is begun. Allowance will be made to the Contractor for additional material fabricated to correct reported contract plan errors.

505.04 Fabrication. Structural steel shall be fabricated and stored according to the following requirements, except for structures carrying railroad traffic. The AREMA Specifications shall govern fabrication of structures carrying railroad traffic except the requirements of this section shall govern when they are more demanding. Fabrication shall be performed by structural steel fabricators meeting the certification requirements of Article 106.08.

(a) Workmanship and Finish. The workmanship and finish shall satisfy applicable Specification and Code requirements, and any significant deficiencies discovered shall be corrected to the Department's satisfaction.

(b) Storage of Materials. Structural material, either plain or fabricated, shall be stored above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease, or other foreign matter, and shall be protected as far as practicable from corrosion.

(c) Straightening or Curving Material. Straightening shall be done by methods which will not injure the metal. Sharp kinks and bends may be cause for rejection of the material. Heat straightening of AASHTO M 270 Grade 100 & 100W material shall be done only when approved by the Engineer and then only under rigidly controlled procedures.

The Contractor may fabricate curved welded girders by cutting the flanges to the required curvature prior to welding the web. Curved welded girders or rolled beams may be fabricated as a straight unit, and through the application of heat to induce the required curvature. Heat-curving will not be permitted on beams or girders fabricated of AASHTO M 270 Grade 485W (70 W) or 690 & 690W (100 & 100W) steels. Cold bending of beams or girders to the required curvature will be permitted provided the proposed detailed procedures receive the Engineer's approval and the finished member approximates a smooth curve without kinks or twist. When beams or girders are to be heat curved, the Contractor shall satisfy the following requirements:

(1) Type of Heating. Beams or girders may be curved by either continuous or V-type heating. For both types of heating, the flange areas to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is mandatory

when the flange thickness is 30 mm (1 1/4 in.) or greater, and the two surfaces shall be heated concurrently. The heating shall progress along the top and bottom flange at approximately the same rate. Heating shall be performed using multiorfice (rosebud) heating torches manipulated to avoid overheating. Torches shall use air-propane or air-natural gas unless other methods are approved by the Engineer for the specific girder configuration. When heating thick plates, it may be necessary to interrupt heating for periods of less than one minute to allow the heat to soak into the flange and avoid surface over-heating.

For the continuous method, strips centered approximately 50 mm (2 in.) inside the edge of the top and bottom flanges shall be heated simultaneously. The strips shall be of sufficient width and temperature to obtain the required curvature.

For the V-type heating, the top and bottom flanges shall be heated in truncated triangular areas spaced at regular intervals along each flange. The heat patterns applied to the inside flange surface shall terminate just before reaching the juncture of the web and the flange. For curvature radii greater than 300 m (1000 ft), heating patterns on the outside flange surfaces shall have their apex coincide with the plane of the web centerline and for smaller radii, the outside patterns shall extend past the web centerline a distance of 1/8 of the flange width or 75 mm (3 in.), whichever is less.

Beginning at the truncated end of each heating pattern, heating shall progress toward the base of the pattern, spreading with an included angle of 15 to 30 degrees. The base of the pattern shall not exceed 250 mm (10 in.) regardless of flange width and thickness. The heating torch progresses toward the base of the heating pattern after the truncated end of the truncated pattern reaches the specified temperature. Once heating begins to progress towards the base at the pattern, the heating torch(es) shall not be returned to the apex of the heating triangle. Heat pattern spacing and size shall be as required to obtain the required curvature.

The Contractor may propose variations in the preceding patterns and methods for the approval of the Engineer.

The maximum temperature shall be prescribed below. If chording or twisting occurs in the member that is unsatisfactory to the Engineer, the Contractor shall correct the situation using Engineer-approved methods to obtain acceptable results.

(2) Temperature Control. Heat curving shall be conducted so that the internal temperature of the steel does not exceed 620 ºC (1150 ºF). “Internal steel temperature” shall be represented by the surface temperature approximately five seconds after passage of the torch. Heating shall be confined to the planned patterns or areas, and shall bring the steel within the pattern to the desired temperature as rapidly as possible without overheating. The temperature range shall be documented, based on frequent monitoring with appropriate

temperature indicating crayons or other calibrated equipment during the heating and cooling of the member. Any procedure which causes the internal steel temperature to exceed 620 ºC (1150 ºF) will be considered destructive heating and be cause for rejection of the member. Steel rejected for overheating may be investigated for reacceptance or repair by tests acceptable to the Engineer. The costs of such tests shall be borne by the Contractor.

After completing a planned set of heat patterns along the member's length, additional heat shall not be applied until the entire member has cooled below 70 ºC (160 ºF) and the net displacement has been verified. Accelerated cooling with water or water mist will not be permitted. Cooling with dry compressed air will be permitted after the steel has cooled to 315 ºC (600 ºF).

(3) Position for Heating. Members may be heat-curved with the web either vertical or horizontal. When curved in the web-vertical position, the member shall be braced or supported so that the lateral deflection will not cause instability. When curved in the web horizontal position, the member shall be supported near its ends and have limiting blocks at intermediate points as to obtain the desired curvature. Restraints or preloads may be used to facilitate heat-induced steel movements, but additional external loads shall not be applied to heated steel. Preloads, including the member's self-weight, shall not cause stresses exceeding 50 percent of the material's nominal yield at ambient temperature.

(4) Sequence of Operations. Members shall be heat-curved before they are painted. The heat curving may be conducted either before or after transverse intermediate stiffeners are installed. Unless provisions made for girder shrinkage, connection and bearing plates shall be located and attached after heat-curving. If longitudinal stiffeners or cover plates are required, they shall be curved separately and then welded to the previously curved girder.

Girders shall be fabricated to specified cambers by cutting web plates to the required geometries before attaching flanges. Heating may be used for small camber corrections if the method and points of application are approved by the Engineer. The prescribed camber shall be obtained before heat-curving and the Contractor shall make allowance for any anticipated losses during fabrication. Rolled shaped shall not be shop cambered, unless otherwise specified. If the contract requires cambering rolled shapes or if straightening as received material is necessary, proposed procedures must be submitted for the Engineer's approval.

Horizontal curvature and vertical camber will not be measured for final acceptance until all heating and welding operations are completed and the flanges have cooled to a uniform temperature. Horizontal curvature will be checked with the beam or girder in upright position.

(d) Fastener Holes. All fastener holes shall be either punched or drilled. In all cases hereafter, drilling may be substituted for punching of full size holes;

subdrilling may be substituted for subpunching; and holes may be drilled in assembly ("from the solid") instead of being subpunched or subdrilled and reamed. Drilling in assembly shall be done with the material in the same configuration required for reaming. Holes punched or drilled full size shall be 2 mm (1/16 in.) larger than the nominal diameter of the fasteners. Subpunched holes for fastener diameters greater than 15 mm (5/8 in.) shall be 5 mm (3/16 in.) smaller than the nominal diameter of the fasteners and for smaller fasteners, the holes shall be subpunched to the fastener's nominal diameter. Subpunched or subdrilled holes shall be reamed to 2 mm (1/16 in.) larger than the nominal diameter of the fasteners.

Holes in carbon steel thicker than 20 mm (3/4 in.) or alloy steel thicker than 16 mm (5/8 in.) shall be drilled or subdrilled and reamed. Punching or subpunching shall not be permitted.

Where reaming is not required, holes in carbon steel up to 20 mm (3/4 in.) thick or in alloy steel up to 16 mm (5/8 in.) thick may be punched to their final specified size.

Holes for main truss or arch connections, field connections of skewed portals; splices or rigidly framed end connections of main beams or girders and rigid frames carrying design loads shall be subpunched and reamed with members assembled in the shop. For beams and girders, his assembly may be made in the web-horizontal position, except horizontally curved members shall be assembled with the web-vertical, unless web-horizontal assembly is approved by the Engineer.

The assembly, including the camber, alignment, accuracy, of subpunched holes and mill-to-bear joints shall be approved by the Engineer before reaming is commenced.

Holes may be punched or drilled to their final specified size for field connections of secondary items including: lateral bracing for girders, truss cords and arch ribs; hanger supports for laterals and utilities; portal and sway bracing; and cross frames or diaphragms than do not require reamed holes. All holes for end field connections of floor beams shall be subpunched or subdrilled to a hardened steel template, and corresponding holes in the members to which they connect shall be reamed to the same template, or these connections may be reamed with the members assembled. Stringer connections to floor beams may have holes punched or drilled to their final specified size. Reaming templates shall have hardened steel bushings and reference lines inscribed to locate the template on the members.

Computer-numerically-controlled (CNC) equipment may be used to produce full sized holes in components otherwise requiring reamed, subsized holes, subject to the Engineer's approval and the demonstrated accuracy of the CNC system. Accuracy must be verified by periodic check assemblies of components, and the Contractor's quality control plan for the system must be acceptable to the Engineer. Errors detected by check assemblies will require additional assemblies to define the extent of problems and

subsequent CNC work may be restricted or prohibited until system corrections are accepted by the Engineer.

(1) Punched Holes. The diameter or the die shall not exceed the diameter of the punch by more than 2 mm (1/16 in.). Holes shall be cleanly cut, without torn or ragged edges.

(2) Accuracy of Unreamed Holes. All subdrilled or subpunched holes shall be so accurate that after steel is assembled and before reaming, a cylindrical pin 3 mm (1/8 in.) smaller in diameter than the punched hole may be inserted perpendicular to the face of the member, without drifting, through at least 75 percent of the holes in the connection or the pieces will be rejected. Holes punched or drilled to their final specified size without assembly shall be so accurate that fasteners may be installed without reaming or additional drilling.

(3) Reamed or Drilled Holes. Reaming and drilling shall be perpendicular to the faying (contact) surface of the connection. Drilling shall be done with twist drills and reaming with fluted or adjustable reamers. Where practical, reaming shall be directed by mechanical means, and done after all the components are assembled and firmly secured. Unless otherwise approved by the Engineer, assembled parts shall be taken apart for removal of cutting oil, shavings, and burrs caused by drilling and reaming.

(4) Accuracy of Reamed and Drilled Holes. Where full size holes are reamed, drilled from the solid, or made by CNC equipment, 85 percent of the holes in any group shall show no offset greater than 1 mm (1/32 in.) between adjacent thickness of metal.

(5) The Contractor shall be responsible for the accuracy of all holes, regardless of tolerance in dimensions of rolled sections or fabricated members. If the required accuracy cannot be obtained otherwise, holes shall be drilled with the members assembled.

(e) Connections. All shop and field connections of structural elements shall be bolted using high-strength steel bolts.

(f) Bolts and Bolted Connections

(1) Turned Bolts. Turned bolts shall have a finishing cut. Holes for turned bolts shall be reamed or drilled 1 mm (1/32 in.) larger in diameter than the bolt. The threads of each turned bolt shall be entirely outside the grip of the metal. A washer 6 mm (1/4 in.) thick shall be used under each nut.

(2) High-Strength Steel Bolts. Bolted parts shall fit solidly together when assembled. Contact surfaces, including those adjacent to bolt heads, nuts, or washers, shall be free of all mill scale, dirt, burrs, and other defects that would prevent solid seating of all parts. Methods of installation and tightening shall conform to the “Specification for Structural Joints Using ASTM A 325M (A 325) or A 490M (A 490) Bolts”,

for slip-critical connections as issued by the Research Council on Structural Connections Joints of the Engineering Foundation, except as follows.

To insure solid seating of all parts of a slip-critical connection, no visible gap shall remain between the faying surfaces when all bolts are tightened to the snug tight condition, producing a bolt tension of approximately 45 kN (10,000 lb). All high-strength bolts shall have a hardened washer under the element (nut or bolt head) turned in tightening regardless of the method used in tightening.

Inspection will be according to the requirements of the latest issue of the Specifications for Structural Joints using ASTM A 325M (A325) or A 490 M (A490) bolts for slip-critical connections. The Contractor shall provide at his/her own expense a calibration device capable of indicating bolt tension. The calibration device shall be capable of testing the shortest bolt length encountered on the structure down to the following minimum lengths:

50 mm (2 in.) for M16 and M20 (5/8 in. and 3/4 in.) diameter bolts

60 mm (2.25 in.) for M22 (7/8 in.) diameter bolts

65 mm (2.5 in.) for M26 (1 in.) diameter bolts

The following fastening systems and methods will be allowed as options to the Contractor for all high-strength bolted connections. The Calibrated Wrench method will not be permitted.

Load Indicating Washer System.
Twist-off Type Fastener System.
Lock-pin and Collar Type Fastener System.
Turn-of-the-Nut method.

The Contractor shall furnish at his/her own expense a calibrated dial inspection torque wrench for use by the Engineer.

Prior to its actual installation, a representative sample of not less than 3 fasteners of each diameter, length and grade will be checked at the job site in the calibration device for approval. If any fastener fails to meet the required minimum tension, the lot it was taken from will be rejected.

After all erection pins are removed, the fasteners in all holes of the connection shall be initially brought to a snug tight condition, approximately 44.5 kN (10,000 lb), progressing systematically from the most rigid part of the connection to the free edges in a manner minimizing relaxation of previously tightened fasteners. When testing for acceptance, the snug tight condition may be verified on the calibration device prior to failure.

After all fasteners in the connection are snug tight, they shall be fully tightened progressing systematically from the center most rigid part of the connection to its free edges.

For the Twist-Off or Lock-Pin and Collar fastener systems, the exposed end of the fastener, where the splined or pintailed end breaks away, shall be cleaned with a wire brush or power tool prior to painting. After cleaning, the exposed end shall be given one coat of an approved high-build aluminum epoxy mastic and then painted with the paint specified for field painting the structure. The minimum dry film thickness of the aluminum epoxy mastic coating shall be 127 microns (5.0 mils). The fastening systems shall meet the following requirements:

a. Load Indicating Washer System. The direct tension indicator shall be according to ASTM F 959, except the average gap for giving the required minimum bolt tension shall be 127 micron (.005 in.) for galvanized bolts.

    1. Testing. The calibration device shall have an adapter for checking the direct tension indicator when placed under the bolt head. The bolts shall be assembled with the direct tension indicator as they are to be installed in the field, including lubrication. Both the turn required by the impact wrench and the tension in kN (lb) shall be determined at snug tight, 381 micron and 127 micron (.015 in. and .005 in.) gaps. This calibration test shall demonstrate that each bolt develops a tension not less than five percent greater than the tension required when the direct tension indicator average gap is 127 micron (.005 in.). Average gap shall be measured according to Table 4 of ASTM F 959. If the bolt does not develop the minimum required tension at 127 micron (.005 in.) gap with the direct tension indicator, the lot represented by the direct tension indicator will be rejected.

    2. Installation. The galvanized direct tension indicator shall be assembled under the bolt head with the protrusions bearing against the underside of the bolt head and shall not be placed under the element turned for tightening. A galvanized hardened washer shall be provided under the nut. For plain finished bolts the direct tension indicator may be placed under either the bolt head or the nut. A hardened washer shall be used between the direct tension indicator and the turned element with the protrusions bearing against the hardened washer.

        The Engineer will check the gap with gap gages. The Contractor shall supply a sufficient number of 25 micron, 127 micron and 381 micron (.001, .005 and .015 in.) gages for inspection purposes.

        Torque wrenches shall only be used as needed for verification purposes. Overtightening may produce total zero gaps. Total

zero gap occurs when a 25 micron (.001 in.) feeler gage cannot enter any gap in the direct indicating washer. No more than ten percent of the bolts with total zero gap in any one connection will be allowed. If the amount of the total zero gap bolts exceeds ten percent of the bolts in the connection, the Contractor shall be responsible, at his/her own cost, for the removal and replacement of these bolts to bring the percent within the ten percent allowed. No more than ten percent of the galvanized bolts will be allowed per connection with gaps between 127 micron and 381 micron (.005 and .015 in.) or over 381 micron (.015 in.) for plain finish bolts. If there are more than ten percent of these bolts per connection, additional tightening will be required to reduce the number of excessive gaps to less than ten percent of the total number of bolts. The Engineer will check 100 percent of the gaps of the first two connections with feeler gages for each bolting crew. Testing at 100 percent will continue if the bolt tightening does not meet the above requirements. Once the above bolting requirements are met, a minimum of 20 percent but not less than ten bolts of each connection and only one bolt of each cross frame or diaphragm connection will be tested with feeler gages. The remainder of the bolts will be visually inspected. If ten percent of this sampling is total zero gap or ten percent greater than 127 micron (.005 in.) gap, the entire connection will be tested.

b. Twist-off Type Fastener System. This method of joint assembly and tightening of connections shall be achieved by the use of a twist-off type fastener system meeting the requirements of section 2(d) of the Specifications for Structural Joints using ASTM A325M (A 325) or A490M (A 490) Bolts. The twist-off bolts shall consist of a threaded bolt with a splined end extension that shears off at a given torque.

c. Lock-pin and Collar Type Fastener System. This method of joint assembly and tightening of connections shall be achieved by the use of a lock-pin and collar type fastener system meeting the requirements of section 2(d) of the Specifications for Structural Joints using ASTM A325M (A 325) or A490M (A 490) Bolts. The lock-pin shall be round headed with a pintail that yields at a given load and the collars shall be of the flanged type and equipped with tablocks to prevent slipping during installation.

A galvanized hardened washer according to AASHTO M 293 may be used under the bolt head for joint thickness adjustment provided the installed fastener conforms to the maximum permissible dimensions “A” and “B” from inspection charts provided by the supplier. Loose or relaxed fasteners shall be removed and replaced with new fasteners to the satisfaction of the Engineer. Each fastener will be visually inspected according to the inspection charts provided by the supplier.

The “A” dimension from inspection charts provided by the supplier may be increased to 3 mm (1/8 in.) and still meet all published values, provided there is no requirement to meet ASTM specifications pertaining to locking grooves (threads) in the shear plane.

A properly installed high tensile fastener shall possess the dimensional characteristics from inspection charts provided by the supplier. Should the dimensions “A” or “B” exceed the indicated values, the fastener is being used out-of-grip. A “C” dimension of less than the values specified is an indication of incomplete swage. A “D” dimension exceeding the tabulated values is an indication of an incorrect or worn anvil on the installation tool. Fasteners falling outside of these ranges shall be removed and replaced.

d. Turn-of-the-Nut Method. This method of joint assembly shall be according to Section 8(d)(1) of the Specifications for Structural Joints using ASTM A325M (A 325) or A490M (A 490) Bolts, except as follows:

1. Installation. After all bolts in a connection are brought to a “snug tight” condition, the outer face of the nut, the turning element shall be match-marked with the protruding portion of the bolt to visually determine the relative rotation occurring between the bolt and the nut during the process of final tightening. If the element to be turned is the bolt head, it shall be match-marked with the plate. The wrench operator shall make marks with a permanent ink type marker or other approved means.

   For connections with 25 mm (1 in.) and thicker plates, a minimum of two cycles of systematic snug tightening will be required to minimize relaxation of previously tightened fasteners prior to final tightening.

2. Inspection. Bolts tightened by the Turn-of-the Nut Method may be accepted by the Engineer on the basis of a visual inspection of the match-marks on the bolts.

(3) Rotational Capacity tests for High-Strength Steel Bolts. Rotational Capacity tests are required for the Turn-of-the-Nut Method, Load Indicating washer and Twist-Off type fastener Systems.

a. Manufacturing. Hardness for bolt diameters M16 to M36 (1/2 in. to 1 in.) inclusive shall be as follows:

Hardness Number

Bolt Size Inclusive	Brinell Min.	Brinell Max.	Rockwell C Min.	Rockwell C Max.
1/2 to 1 in.	248	311	24	33

	Vickers Min.	Vickers Max.	Rockwell Min.	Rockwell Max.
M16 to M36	255	336	C23	C34

b. Testing. For galvanized washers, hardness testing shall be performed after galvanizing. The coating shall be removed prior to taking hardness measurements.

Rotational-capacity tests will be required and will be performed on all black or galvanized (after galvanizing) bolt, nut, and washer assemblies by the manufacturer or distributor and the following requirements shall be met prior to shipping:

1. The rotational-capacity test shall be performed according to AASHTO M 164M (M164).

2. Each combination of bolt production lot, nut lot, and washer lot shall be tested as an assembly.

3. A rotational-capacity lot number shall be assigned to each combination of lots tested.

4. The minimum frequency of testing shall be two assemblies per rotational-capacity lot.

5. The bolt, nut, and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.

   Bolts too short to test in a tension calibrating devise shall be tested in a steel joint. The tension requirement specified in (7) need not apply. The maximum torque requirement specified in (8) shall be computed using a value of P equal to the turn test tension shown in the table in (7).

6. The minimum rotation, from a snug tight condition (ten percent of the installation tension), shall be:

   240° (2/3 turn) ≤ 4 diameters bolt length
   360° (1 turn) > 4 diameters ≤ 8 bolt diameters bolt length
   480° (1 1/3 turn) > 8 diameters bolt length

7. The tension reached at the above rotation shall be equal to or greater than 1.15 times the required installation tension. The installation tension and the tension for the turn test shall be as follows:

Diameter (mm)	16	20	22	24	27	30	36
Req. Installation Tension (kN)	94	147	182	212	275	337	490
Turn Test Tension (kN)	108	169	209	244	316	388	564

Diameter (In.)	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
Req. Installation Tension (kips)	12	19	28	39	51	56	71	85	104
Turn Test Tension (kips)	14	22	32	45	59	64	82	98	120

8. After the required installation tension listed above has been exceeded, one reading of tension and torque shall be taken and recorded. The torque value shall conform to the following:

   Torque less than or equal to 0.25 PD
   Where:
   Torque = measured torque kN m (ft lb)
   P = measured bolt tension kN (lb)
   D = bolt diameter m (ft)

c. Reporting.

   1. The results of all tests specified including zinc coating thickness and the appropriate AASHTO tests shall be documented.
   2. Location where tests are performed and data of tests shall be documented.

d. Witnessing. The tests need not be witnessed by an inspection agency. The manufacturer or distributor that performs the tests shall certify the results recorded as accurate.

e. Documentation.

1. Mill Test Report(s) (MTR).

(a.) MTR shall be furnished for all mill steel used in the manufacture of bolts, nuts, or washers.
(b.) MTR shall indicate where the material was melted and manufactured.

2. Manufacturer Certified Test Report(s) (MCTR).

(a.) The manufacturer of the bolts, nuts, and washers shall furnish MCTR for the item furnished.

(b.) Each MCTR shall show the relevant information according to the reporting of the testing required.

(c.) The manufacturer performing the rotational-capacity test shall include on the MCTR:

(1.) The lot number of each of the items tested.

(2.) The rotational-capacity lot number according to Article 505.04(f)(3) b. 3.

(3.) The results of the tests required in Article 505.04(f)(3) b.

(4.) The information required in Article 505.04(f)(3) c.

(5.) A statement that MCTR for the items are according to this specification and the appropriate AASHTO specifications.

(6.) The location where the bolt assembly components were manufactured.

3. Distributor Certified Test Report(s) (DCTR). The DCTR shall:

(a.) Include MCTR above for the various bolt assembly components.

(b.) Include rotational-capacity tests by either the manufacturer or the distributor.

(c.) Show the results of the tests required in Article 505.04(f)(3) b.

(d.) Show the pertinent information required in Article 505.04(f)(3) c.

(e.) Show the rotational-capacity lot number as required in Article 505.04(f)(3) b.

(f.) Shall certify that the MCTR are in conformance to this specification and the appropriate AASHTO specifications.

f. Shipping.

1. Bolts, nuts, and washers from each rotational-capacity lot shall be shipped in the same container. When there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. Each container shall be permanently marked with the rotational-capacity lot number such that identification will be possible at any stage prior to installation. The rotational-capacity lot number shall be placed on both the container itself and the lid.

2. The appropriate MTR, MCTR, or DCTR shall be supplied to the Engineer.

g. Installation. The following requirements for installation shall apply prior to the installation of high-strength bolts

1. The rotational-capacity test described in Article 505.04(f)(3) b. above shall be performed on each rotational-capacity lot at each job site prior to the start of bolt installation. If any bolt fails to meet the required minimum tension, the lot from which it was taken will be rejected.

2. Lubrication.

(a.) Galvanized nuts shall be checked to verify that a visible lubricant is on the threads.

(b.) Black bolts shall be "oily" to the touch when delivered and installed.

(c.) Slightly weathered or lightly rusted bolts or nuts that fail to meet the above requirements shall be cleaned and relubricated prior to testing. Recleaned or relubricated bolt, nut, and washer assemblies shall be retested according to the rotational capacity test, prior to final installation.

3. Bolt, nut, and washer combinations as installed shall be from the same rotational-capacity lot.

(g) Shop Assembling. Flange splice plates shall be fabricated with the primary rolling direction parallel to the member's longitudinal centerline. Web splice plates, connecting plates, gusset plates and stiffeners may have their

primary rolling direction in either direction. Parts of a member shall be assembled, well pinned and/or firmly drawn together with bolts before reaming or tightening of fasteners is commenced. The member shall be free from twists, bends, and other deformations that would prevent the solid seating required under Article 505.04 (f)(2). A 3 mm (1/8 in.) or greater difference in plate thickness or member depths across a bolted splice shall be rectified with shims included during reaming, match marked and shipped with member.

Parts not completely fastened in the shop shall be secured insofar as practicable to prevent damage in shipment and handling . Members assembled in the shop for reaming of field connections shall remain assembled until shop inspection by the Department has been made.

Fitting-up and shipping bolts, templates, jigs, shipping or shop assembly braces, and other items provided by the shop for fabrication or shipping but not incorporated in the final structure are considered incidental to the fabrication of the steel and will not be paid for as structural steel.

(h) Drifting of Holes. The drifting done during shop assembly shall bring parts into position, but shall neither enlarge the full size holes nor induce permanent distortion in any portions of the final structure.

(i) Match Making. All parts of connections reamed or drilled in assembly shall be individually match marked while assembled and a diagram showing such marks shall be included in the shop detail drawings. Individually match marked items shall not be interchanged.

(j) Stamping of Members for Identification. Any metal die stamping of steel members shall be done using low or mini-stress dies. Letters and numbers shall be 10 mm (3/8 in.) or 12 mm (1/2 in.) tall. When used, the dies shall be lightly struck to produce an impression that can be clearly seen in the absence of paint and mill scale.

(k) Thermal Cutting. Structural steel or wrought iron may be thermally cut, provided that a smooth, accurate profile, free from cracks and notches, is obtained by the use of a mechanical guide. Hand cutting of material remaining in the final structure shall be done only where approved by the Engineer, and shall be followed by grinding.

Reentrant cuts shall have a radius of not less than 20 mm (3/4 in.) and be finished to an ANSI surface roughness not exceeding 12 micrometers (500 microinches).

Surface roughness exceeding the applicable limits of Article 505.04 (l) (2) or the BWC and gouges not more than 5 mm (3/16 in.) deep on thermal cut edges (TCEs) shall be removed by machining or grinding and be faired to the surface with a slope of 1 to 10 or less. Gouges due to thermal cutting or handling damage that are more than 5 mm (3/16 in.) deep may be repaired according to the BWC using a procedure approved by the Engineer for the material type and thickness involved. The completed weld shall be ground

to match the adjacent surface and inspected by MT or UT, as approved by the Engineer.

(l) Finishing.

(1) Edge Planning. Sheared edges of material more than 16 mm (5/8 in.) thick and carrying calculated stress shall be planed to a depth of 6 mm (1/4 in.). Sheared edges of material up to 16 mm (5/8 in.) thick and carrying calculated stress shall be planed to a depth of 6 mm (1/4 in.). Sheared edges of material up to 16 mm (5/8 in.) thick which carry calculated stress shall be planned to a depth of not less than 3 mm (1/8 in.) unless enclosed by welds. Sheared edges of material not carrying calculated stress and exposed after fabrication shall be ground or planed to remove evidence of tearing and sharp corners.

(2) Facing of Bearing Surfaces. The top and bottom surfaces of steel pedestals, bolsters, column cap an base plates, and masonry (base) plates shall be planed or otherwise finished as necessary to be within 2 mm (1/16 in.) of planar. Cast pedestals shall be planed on surfaces that are to in contact with steel and shall be finished to a maximum of ANSI roughness not exceeding 50 micrometers (2000 microinches) on surfaces in contact with masonry, leveling plates, or pads.

The surface finish or bearing and base plates and other bearing surfaces that come in contact shall meet the following requirements as defined in ANSI B 46.1, Surface Roughness, Waviness and Lay, Part 1:

Steel slabs …….	ANSI 50 micrometers	2000 microinches
Heavy plates in contact in Shoes to be welded	ANSI 25 µ m	1000 µ in
Milled or faced ends of compression members, milled or ground ends of stiffeners ……	ANSI 12 µ m	500 µ in
Bridge rollers and rockers	ANSI 6 µ m	250 µ in
Pin holes……	ANSI 3 µ m	125 µ in
Sliding self-lubricating bearings	ANSI 3 µ m	125 µ in

Bronze or copper-alloy bearing plates shall be self-lubricated by special graphited and metallic inserts. The manufacturer's proposed materials and methods for producing the bearing plate shall meet with the approval of the Engineer.

(3) Abutting Joints. Abutting joints in compression members shall be faced and brought into uniform bearing, with no gaps exceeding 1 mm (1/32 in.), before welding or producing full size holes during shop assembly. Abutting joints in tension members and at beam or girder splices need not be faced but the clearance within field bolted connections shall be from 2 mm (1/16 in.) to 6 mm (1/4 in.).

(4) End Connection Angles. End connection angles of floor beams and stringers shall be coplanar and positioned for the length of the member with such accuracy that milling to the exact member length will not reduce their thickness by more than 3 mm (1/8 in.).

(5) Corner Grinding. All outside corners remaining after shop fabrication shall be free of abrupt irregularities and dull to the touch. Fins, burrs, cutting slag, significant deformities, gouges, sharpness (corner more acute than 1 mm (32 in.) radius, and other hazards to handling or impediments to proper coating application and performance shall be corrected by grinding and/or other Engineer-approved methods. Corners of the thermally cut edges on main stress carrying members shall be treated according to the BWC. When painting is required, it shall be done according to Article 506.03.

(6) Fit of Stiffeners. For bolted construction, end stiffener angles of girders and stiffener angles intended as supports for concentrated loads shall be milled or ground to secure an even bearing against the flange angles or beam flanges with no gaps exceeding 1 mm (1/32 in.).

For welded construction, bearing stiffeners shall be milled or ground to bear at the bearing ends and a tight fit provided at the other ends.

(m) Links. Links for pin and link hanger assemblies or bearings experiencing uplift shall be fabricated from rolled plate. The primary plate rolling direction shall be along the length (vertical axis) of the link. The material shall have a minimum Charpy V-Notch toughness of 48 J (35 ft lb) at –7 ºC (20 ºF) and a minimum elongation of 22 percent in 50 mm (2 in.). Yield strength of the link material shall not exceed 480,000 kPa (70 ksi). The links shall be straight and parallel. Holes in links and webs for pins or bushings shall have a maximum roughness equivalent to 3 micrometers (125 microinches) finish.

(n) Rollers and Pins. Rollers and pins shall be straight and turned to the dimensions shown on the drawings. The final surface shall be produced by a finishing cut, except expansion rollers made from cold finished steel bars having a smooth, true surface, need not be turned. Pins for pin and link assemblies or bearings with uplift shall have a ground finish equivalent to a 0.8 micrometers (32 microinches) maximum roughness and shall be 100 percent inspected by magnetic particle or dye penetrant testing after grinding. Any cracks or other flaws detected shall be reported to the Engineer and will be cause for rejection. After testing, unpainted carbon steel pins shall be coated for corrosion protection according to Article 506.04 (h). Rollers shall be shop primed after testing.

(o) Boring Pin Holes. Pin holes shall be bored at right angles with the axis of the member and parallel to each other unless otherwise required. The actual distance from center to center of pins at link connections shall not vary from that specified by more than 3 mm (8 in.). The boring shall be done after the member is fabricated. If metallic pin bushings are required, they shall be shrunk fit and their internal diameters shall be ground to 0.8 micrometer (32 microinches) maximum roughness.

(p) Pin Clearances. For steel-on-steel contact, the fit between a hole and a pin shall be according to ANSI Standard B4, Class RC8, loose running fit. For pins bearing on metallic shrink fit bushings, the fit shall be ANSI B4, Class RC7. For pins bearing on Teflon Impregnated fiber reinforced bushings, the bushing manufacturer's recommended tolerances for fit shall be followed for the hole and pin diameters. Tolerances for all pin diameters and pin holes shall satisfy the following:

Nominal Diameter	Range of Clearance	Tolerance from Nominal Sizes	
		Hole	Pin
mm	μm	μm	μm
50-80	152-343	+114 0	-152 -229
80-120	178-394	+127 0	-178 -267
120-180	203-457	+152 0	-203 -305
180-250	254-546	+178 0	-254 -368
250-315	305-635	+203 0	-305 -432
315-400	356-737	+229 0	-356 -508
Nominal Diameter	Range of Clearance	Tolerance from Nominal Sizes	
		Hole	Pin
(in.)	(in. x 10^{-3})	μm	μm
1.97-3.15	6.0-13.5	+4.5 0	-6.0 -9.0
3.15-4.73	7.0-15.5	+5.0 0	-7.0 -10.5
4.73-7.09	8.0-18.0	+6.0 0	-8.0 -12.0
7.09-9.85	10.0-21.5	+7.0 0	-10.0 -14.5
9.85-12.41	12.0-25.0	+8.0 0	-12.0 -17.0
12.41-15.75	14.0-29.0	+9.0 0	-14.0 -20.0

(q) Welding. Welding shall be done according to the requirements of the ANSI/AASHTO/AWS D-1.5, except steel tubular structures shall be covered by the AWS D1.1 Structural Welding Code. Steel shall only be shop welded to remedy minor defects or according to details shown on shop drawings approved by the Engineer. Proposed details and procedures for field welding of structural steel shall be approved by the Engineer before welding begins.

Shop and field welding shall be performed using Welding Procedure Specifications approved by the Engineer with shielded metal arc welding (SMAW), submerged arc welding (SAW), gas metal arc welding (GMAW), or flux cored arc welding (FCAW) consumables permitted by the BWC. Other

processes or consumables shall be specifically authorized by the Engineer on a project by project basis. Welders shall be qualified according to the BWC or Structural Welding Code.

(1) Modifications by Code. The following modifications to the specified sections of BWC shall apply.

(a) In sections 4 and 5 of the BWC, including tables 4.1, 4.2, 4.3 and 4.4, the base metals shown in each row of the following list shall be considered equivalent for the purposes of fabrication and weld procedure qualifications:

Row 1	ASTM		AASHTO	
	A 36M	A 709M Gr. 250	M 183M	M 270M Gr. 250
2	A 572M Gr. 345	A 709M Gr. 345	M 223M Gr. 345	M 270M Gr. 345W
3	A 588M	A 709M Gr. 345W	M222M	M 270M Gr. 345W
4	A 852M	A 709M Gr. 480W	M 313M	M 270M Gr. 480W
5	A 514M	A 709M Gr. 690W		M 270M Gr. 690W
6	A 517M	A 709M Gr. 690W	M 244M	M 270 M Gr. 690

Row	ASTM		AASHTO	
1	A 36	A 709 Gr. 36	M 183	M 270 Gr. 36
2	A 572 Gr. 50	A 709 Gr. 50	M 223 Gr. 50	M 270 Gr. 50
3	A588	A 709 Gr. 50W	M 233	M270 Gr. 50W
4	A 852	A 709 Gr. 70W	M 313	M 270 Gr. 70W
5	A 514	A 709 Gr. 100W		M 270 Gr. 100
6	A 517	A 709 Gr. 100	M 244	M 270 Gr. 100

Charpy-V-notch (CVN) Testing: All CVN testing shall be for Zone 2.

(b) In Section 5 of the BWC, 5.2 requires the Contractor to perform Qualification or Verification testing. The Department will consider each fabrication organization as a separate Contractor for this requirement of the BWC. For fabricators operating in multiple locations, either with a group of buildings or at geographically separates facilities, weld procedures for the same type of equipment, used under similar operating conditions may be based on a common set of Procedure Qualification Reports (PQRs). If

routine nondestructive testing reveals significant disparities in production quality that may be attributed to equipment variation then separate qualification tests shall be done at each location or machine involved. Non-FCM PQRs based on qualification tests, pretests and/or verification tests shall remain valid as long as no significant changes occur in electrode/flux components or properties, subject to evidence of the shop's successful use of the process on equal or greater strength material at least every six months. If more than six months elapse without documented successful use of the process, the Engineer may require requalification of the PQR used to prepare the WPS proposed. Evidence of satisfactory use shall include Fracture Critical procedure tests, nondestructive examination of production welds, or welder/weld operator qualification tests. The Engineer will accept evidence of prior testing provided the PQR is complete and shows compliance with these specifications, and both the witnesses and the facility performing testing are satisfactory.

(2) Electrodes and Flux. Welding electrodes and flux for submerged arc welding shall bear the manufacturer's marking showing the material to be of the proper class. The equipment and consumables to be used shall be submitted to the Engineer for approval, together with evidence of the manufacturer's PQR and the Contractor's verification test(s) or the Contractor's PQR except as exempted.

For flux cored electrodes, only E7XT-6 or E7XT-8 may be used in areas susceptible to drafts or wind exceeding 8 km/h (5 mph). Other flux cored, metal cored or solid electrodes utilizing gas shielding and satisfying the BWC may be used in enclosed, protected environments with air movement of less than 8 km/h (5 mph). Welds made with E7XT-6 or E7XT-8 shall not be covered by or incorporated into welds made with other electrodes.

Ancillary products described by subparagraph 1.3.6 of the BWC shall include: cross frames and diaphragms for non-curved structures and not designed to convey liveload stresses, finger plate assemblies, pedestals and bolsters, retainer angles, walkway grating, ant other items specifically identified by the Engineer.

Electrodes and flux used for welding tubular steel structures and which satisfy prequalification requirements in the AWS D1.1 shall not require qualification testing.

When PQR, Pretests, and/or Verification Tests are not required, variables affecting heat input shall be within ranges specified by consumable manufacturers, and supported by manufacturers' compliance reports not more than 12 months old which shall be in a file maintained by the Contractor and furnished to the Engineer or Inspector upon request. Any parameters (including gas flow, current limits, E.S.O. and polarity) not within the manufacturers' guidelines shall require qualification testing for the WPS. The Quality Assurance (QA) Inspector representing the Department and Contractor's Quality Control

(QC) Inspector shall ensure the Procedure Qualification Test weld parameter variables are being accurately monitored and recorded for each pass, and that specimen identity is constantly maintained. Similarly, the QA Inspector and QC shall assure the critical weld parameters (preheat, travel speed, wire feed speed, current, etc.), consumable condition and weld quality are adequately monitored throughout production.

When repetitive welding deficiencies persist even after adjustments are made, the QA Inspector shall have authority to prohibit use of the Weld Procedure Specification (WPS), consumables involved, welding equipment and/or welding personnel, as applicable, for Department projects until abnormalities are corrected to the QA Inspector's satisfaction. Such deficiencies may include: lack of fusion or penetration; overlap; large or frequent slag inclusions; poor deslagging and interpass cleaning; ropiness; convexity or concavity of bead; gross porosity; and non-uniform weld size. If more serious deficiencies are noted, such as weld or underbead cracking, extensive lack of fusion, wet flux, contaminated weld zone or not conforming to an approved WPS, the QA Inspector may require either removal of questionable welds or additional NDT at the Contractor's expense. If deficiencies are attributable to the WPS or a specific electrode-flux combination, the Engineer will have authority to require the Contractor to either repeat Qualification Testing or to use another approved WPS.

(3) Procedures. Complete Weld Procedure Specifications (WPSs) shall be submitted to the Engineer with fully documented and accepted PQRs (if applicable) for approval. The WPS submitted may be either generic for common situations on multiple projects or be tailored to suit the particular fabrication project.

The WPS shall include the following items: general instructions for fit-up, techniques and welding sequences; types of steel; joint description and preparations; welding position; polarity; amperage, voltage, and linear welding speed; electrode size and type; flux designation and consumable manufacturer's trade name(s); approximate number of passes, maximum width and thickness of weld layers, and any procedure change between passes in the same weld; preheat-interpass temperatures, maximum and minimum; post heat temperature and duration; and other data necessary to fully describe the welding procedure.

(4) Welder Qualification. All welders, welding operators, and tackers shall be qualified by test according to the applicable welding code, at the Contractor's expense. Testing shall be administered and certified by a Certified Welding Inspector (CWI) or equivalent acceptable to the Engineer. The Engineer may accept evidence of previous qualification for welders under the applicable welding specifications.

(5) Fabrication. Shop welded butt splices not detailed on Contract plans but required by limiting lengths of material may be used if they are detailed for the full strength of the member and are placed at locations

approved by the Engineer. Complete joint penetration welds shall not have more than three repair welds made at a common location. Complete removal of the weld and adjacent base metal shall be required after the third repair.

Flange-to-web welds and shop welded splices in flanges or webs shall use the automatic submerged arc welding process. All fillet welding of stiffeners and connection plates to webs shall utilize automatic submerged arc welding unless otherwise approved by the Engineer for specific situations.

If the applicable code permits welding on areas with tight mill scale present, WPSs utilizing consumables with sufficient deoxidizing capacity shall be employed to avoid porosity or lack of fusion. Tack welds shall start a minimum of 75 mm (3 in.) from the end and shall be a minimum of 40 mm (1 1/2 in.).

Ends of fillet welds shall have full throat and no unfilled craters. Fillet welds on stiffeners, connecting plates, gussets, and other assemblies (except for flange-to-web welds) shall terminate approximately 5 mm (1/4 in.) from the end of plate intersects to avoid undercut and other defects.

Special precautions shall be taken when welding during cold weather to avoid extreme thermal gradients and to avoid adversely effecting the manual functions of the welder or welding operator. In certain cases, the BWC minimum preheat and interpass temperatures may be insufficient for steels with nominal yield strengths exceeding 345,000 kPa (50 ksi) and thickness above 20 mm (3/4 in.). Preheat for these steels shall be calculated if the nominal welding electrode strength exceeds 550,000 kPa (80 ksi) and the plate sulfur content exceeds 0.01percent, or if either plate's carbon equivalent exceed 0.4 percent.

Tolerances for welded components shall be according to the applicable welding code except the maximum deviation from specified camber for a span (abutment to-pier or pier-to-pier) or girder segment (abutment-to-splice or splice-to splice) shall be +20 mm (3/4 in.).

Shop butt welds in flanges and webs shall be completed, tested, and accepted before the flanges are assembled on the web. Where possible, extension blocks (run on/run-off tabs) matching the joint's cross section are to be used for all complete penetration welds and flange-to-web welds, unless additional material is provided to ensure full size welds the full length of the member .

(6) Inspection. The inspection of welds and workmanship will be performed according to the BWC except as modified.

Prior to the start if fabrication of their first project for the Department within the previous 24 months, the Contractor's QC and production supervisors and the Engineer shall have a conference to ensure agreement regarding the details of the project, standard shop

procedures, advance notifications to the Inspector, specific items for QC/QA acceptance, material documentation, cleaning and painting requirements, the sequence of fabrication to be followed, the status of qualifications for welders and welding operators, and approval of electrodes, wire, flux, other welding materials and equipment.

The welding and testing of all Procedure Qualification Test specimens shall be witnessed by personnel from two separate agencies, independent of the fabricator and acceptable to the Engineer. These may include the Inspector, Inspectors from other state DOTs, and/or qualified individuals from independent testing agencies which meet the approval of the Engineer.

In addition to visual inspection of all welds, radiographic, ultrasonic, and magnetic particle inspection may be required. The mandated radiographic, ultrasonic, and magnetic particle non-destructive testing (NDT) shall be performed by the Contractor and the cost shall be included in the price bid for fabricating (shop NDT) or erecting (field NDT) structural steel.

Butt welds shall be radiographically inspected in accordance with the BWC except: top and bottom 1/3 of each vertical web joint shall be tested, and the remainder of that joint tested if unacceptable discontinuities are found in those areas; 50 percent of longitudinal web joints shall be radiographically tested; and, except for webs, joints shall be considered “subject to tension or reversal of stress” if either plate joined requires Charpy V-notch (CVN) testing. In addition, butt welds in which the thickness of the thinner plate equals or exceed 75 mm (3 in.) shall also be ultrasonically inspected. All joints to be inspected shall be free of paint, scale and grease.

All radiographs shall be taken and interpreted by qualified technicians acceptable to the Engineer. The original film and a complete report describing the procedure and the technicians interpretation, properly identified as to piece and location of the weld, shall be submitted to the QA Inspector for approval prior to acceptance of the weld. If the original film is found to be unacceptable by review by the QA Inspector, another radiograph of the joint shall be taken by the Contractor at no additional cost to the Department. In the event the Contractor questions the QA Inspector’s interpretation of the radiographic films, a joint review of the film will be made. The Engineer’s final interpretation will govern.

When areas to be radiographed are too large for one film, individual exposures shall be made for each film used. The limits for one film shall be made for each film shall be 375 mm (15 in.) for web shots and 400 mm (16 in.) for flange shots 30 mm (1 1/4 in.) and thicker the limits shall be 375 mm (15 in.).

If radiographic inspections disclose rejectable defects, they shall be repaired and additional radiographs shall be taken for each repaired weld, at the expense of the Contractor, and submitted to the QA Inspector for approval.

The Contractor shall furnish the Engineer a shop drawing with the weld identification and showing assembly of the steel into final members or pieces. Lettering on radiographs of repairs shall show an “R” and the number of the repair shot. This additional identification shall be placed next to the film number and be included on the weld identification shop drawing.

Location marks shall be stamped in the steel by the Contractor prior to radiographing, using a prick punch with a dull tip. These will be located by lead arrows, but only the “floating” mark must be visible on the film. The location marks shall consist of center punch marks 40 mm (1 1/2 in.) from the centerline of the weld for plates up to 75 mm (3 in.) thick or 50 mm (2 in.) from the centerline on thicker plates, and 60 mm (2 1/4 in.) in from each edge of the plate. In addition, there shall be one randomly placed, “floating” punch mark within each exposure at the same distance e from the centerline. The punch marks shall be placed in the thinner plate. In a series of overlapping exposures, the location marks shall be placed at approximately every 375 mm (15 in.).

Complete penetration tee and corner joints of primary members shall be ultrasonically inspected. Complete penetration tee and corner joints in compression or shear shall have at least 300 mm (1 ft) of every 1.3 m (4 ft) and 300 mm (1 ft) of each joint less than 1.2 m (4 ft) ultrasonically inspected. This shall include flange-to-web welds in bending members and welds joining material that does not require Charpy V-notch (CVN) testing. If unacceptable defects are found in any test length, the full length of the weld or 900 mm (3 ft) either side of the test length, whichever is less, shall be ultrasonically inspected. If unacceptable defects are found in more than 20 percent of the 300 mm (1 ft) increment lengths tested, the full length of the joint shall be ultrasonically inspected. Complete penetration tee and corner joints subject to tension or stress reversal shall be ultrasonically inspected the full length of the joint. This shall include welds jointing plates requiring CVN testing other than web-to-flange joints in bending members. Welds within 300 mm (1 ft) of repairs shall be retested after the repairs are made.

Partial magnetic particle inspection will be required of each fillet weld on nonfracture critical girders, floor beams, stringers and truss members, fabricated items subjected to tensile stress or reversal of stress and for root and final passes of partial penetration groove welds in primary members unless specifically exempted by the Engineer. At least 300 mm (1 ft) of every 3 m (10 ft) of weld length or 300 mm (1 ft) of each weld less than 3 m (10 ft) in length, plus welds within 300 mm (1 ft) of all starts and stops shall be tested, except bearing assembly to flange and diaphragm seat angle to web welds shall only be tested when visual inspection indicates possible flaws. The test shall be located at random in the members so as to be typical of the welding. Random locations are subject to selection by the Engineer. If unacceptable defects are found in any test length of a fillet weld, the full length of the weld, or 1.5

m (5 ft) on either side of the test length, which ever is lesser, shall be magnetic particle tested.

For Fracture Critical Members (FCM), fillet welds on flanges and webs that may be in tension areas shall receive 100 percent magnetic particle inspection.

The magnetic inspection procedure and techniques shall be according to ASTM E 709. The QA Inspector will examine the magnetic test reports and give approval before the members will be accepted. Welds within 300 mm (1 ft) of repairs shall be retested after the repairs are made.

Welded or cast steel bearing assemblies weighting more than 160 kg (350 lb) each shall be nondestructively examined by visual, magnetic particle and/or ultrasonic methods, as directed by the Engineer to insure no critical flaws exist.

Surface porosity in all welds shall not exceed 5 mm (3/16 in.) in 25 mm (1 in.) of weld nor 10 mm (3/8 in.) in 300 mm (1 ft) of weld. Cluster porosity size shall be determined by describing a circle around the cluster of holes. If the circle diameter is 5 mm (3/16 in.) or greater, the porosity must be ground out and rewelded. For linear porosity, a line connecting three or more adjacent pores shall be drawn. Adjacent pores are defined as pores separated by less than 5 mm (1/4 in.). If the line drawn exceeds 10 mm (3/8 in.) in 300 (1 ft), the porosity shall be ground out and rewelded. The maximum diameter for a single pore shall not exceed 2 mm (3/32 in.). The maximum frequency shall not exceed 1 porosity episode in 100 mm (4 in.) nor 5 (6) episodes for every 1 m (4 ft) of weld. The above criteria shall also apply to all subsurface welds which are critical or heavily stressed welds that are subjected to various nondestructive tests.

The Contractor shall give the Engineer sufficient advance notice of the date on which the material will receive radiographic, ultrasonic or magnetic particle inspection so that the Engineer may be present.

(r) Bent Material. Material that must be bent, shall be produced by techniques approved by the Engineer.

(s) Fillers. Slight inaccuracies in the depths of rolled sections at a connection properties and coating requirements as the material joined and shall not be tack welded.

(t) Screw Threads. Threads for all bolts and pins for structural steel construction shall conform to the Unified Standard Series UNC-ANSI B 1.1, Class 2A for external threads and Class 2B for internal threads, except pins ends having a diameter of 35 mm (1 3/8 in.) or more shall have a thread pitch of 4.2 mm (6 threads to the 1 in.).

(u) Anchor Bolts. Masonry anchor bolts shall be hot-dip galvanized.

505.05 Inspection. All material and workmanship will be subject to QA inspection by the Engineer. The cost of inspection, both at mill and shop, will be borne by the Department, except whenever any inspection is conducted outside the Continental United States, the Contractor shall bear the actual costs of travel and subsistence for the Department's QA inspection.

(a) Shop Inspection. The Contractor shall give the Engineer at least a one week notice prior to the beginning of work for shops within Illinois and at least two weeks notice for work outside state boundaries. The Contractor shall arrange members or units to be inspected so that identification marks are visible and each member or unit is accessible for measurements the QA Inspector may deem necessary. Upon the QA Inspector's request, the Contractor shall reposition the steel to permit full examination. Prior to shop inspection of an item, the Contractor shall furnish the QA Inspector with a list of its main stress carrying material, correlating the piece mark and heat numbers. The heat number, established by the rolling mill, shall be preserved on material through fabrication until the element is joined into a member with a permanent piece mark.

(b) Shop Assembly. All truss panels and arches, whether reamed or punched, shall be completely, geometrically or sequentially assembled at the fabricating plant, subject to the Engineer's approval of the fabricator's proposed system. All steel members in a continuous assembly having reamed field connection holes shall be assembled, unless otherwise noted or approved by the Engineer, before reaming is commenced. Unless approved by the Engineer, assemblies made for reaming or drilling holes shall not be disassembled until shop QA inspection has been made.

(c) Waiving Shop Inspection. The Engineer may partially or completely waive shop QA inspection and complete the inspection of fabricated material when it is delivered at the job site. The Contractor shall remain responsible for the fabricated items until job site acceptance is given.

505.06 Cleaning and Shop Painting. Fabricated steel shall be cleaned and shop painted according to Articles 506.03 and 506.04

505.07 Marking and Shipping. Each member shall receive an erection mark for identification, and an erection diagram showing member locations shall be included in the shop drawings. If paint is used to locate (circle) metal stamped marks or to enhance their legibility (copy) on unpainted structures, the marks shall be placed in areas not highly visible after construction. Paint marks on outside faces of unpainted fascia members or on the underside of their bottom flanges shall be removed at the expense of the Contractor responsible for fabrication.

Pins, small parts and small packages of bolts, washers and nuts may be combined for shipment in boxes, crates, kegs, or barrels, but they shall be protected from damage and the gross weight of any container shall not exceed 135 kg (300 lb). A list and description of the contents shall be attached to the outside of each container. The loading, transportation, unloading, and storing of structural material shall be conducted so that the items will be kept clean and not be excessively stressed, deformed or otherwise damaged. For handling long steel members or large

assemblies, lifting points, temporary supports and sequences, based on the Contractor's calculations, shall insure member stresses do not exceed 80 percent of the material's minimum yield strength. These calculations shall be submitted to the Engineer for review. In storing and shipping members, blocking, bracing, and shoring shall be sized and placed as necessary to prevent excessive deflection or motion. Fabricated beams and girders shall be handled, stored, and shipped in an upright and final erection position unless otherwise approved by the Engineer.

Steel lifting lugs on members will not be permitted if their installation and removal could possibly be detrimental to the structure. The following requirements shall also be met:

(a) One Contract for Fabrication and Erection. When fabrication and erection are accomplished under one contract and lifting lugs are used, the lugs shall be placed during fabrication. When no longer required, the lugs shall be removed.

The location, attachment and removal method for the lugs shall be detailed on the shop drawings approved by the Engineer. This work will not be paid for separately but shall be considered as included in contract unit price bid for furnishing and erecting structural steel, and no additional compensation will be allowed.

(b) Separate Contracts for Fabrication and Erection. When fabrication and erection are accomplished under separate contracts and lifting lugs are desired by the erector but not shown on the contract plans, the erection Contractor shall be responsible for submittal of shop drawings to the Engineer for approval and for having the lugs furnished, installed and removed. When lifting lugs are detailed on the contract plans, the fabrication Contractor shall be responsible for furnishing and installing the lugs and the erection Contractor shall remove them when no longer required. The location, attachment and removal method for the lugs shall be detailed on the shop drawings and approved by the Engineer.

This work will not be paid for separately and no additional compensation will be allowed. When the lugs are shown on the fabrication contract plans, the cost of furnishing and installing the lugs shall be considered as included in the contract unit price bid for furnishing structural steel, and the cost of removal of the lugs and repair of the paint or base metal, if required, shall be considered as included in the contract unit price bid for erecting structural steel. When lugs are not shown on the fabrication contract plans, the entire cost involved in furnishing, installing and removing the lugs shall be considered as included in the contract unit price bid for erecting structural steel.

505.08 Erection. The Contractor shall erect the structural steel, remove the temporary construction associated with the steel erection and do all work required to complete the structure as covered by the contract. The following requirements shall govern:

(a) Masonry. If the substructure and superstructure are built under separate contracts, the Department will provide the masonry, constructed within

allowable tolerances for lines and elevations, and properly finished, and will establish the locations and elevations required for setting the steel.

(b) Plant. The Contractor shall provide the falsework and all tools, machinery and appliances, including pilot and driving nuts, drift pins and fitting-up bolts, necessary for the expeditious handling of the work. These items will be considered as equipment and shall remain the property of the Contractor.

(c) Handling and Storing. The loading, transporting, unloading, storing and handling of structural steel shall be according to Article 505.07 and shall be conducted so that the members will be kept clean and free from injury. When unloaded, the materials shall be placed on skids and braced to prevent excessive deflection, to keep the member off the ground and to provide adequate stability.

If the contract covering the erection of the steel does not include the fabrication, the erection Contractor shall check the material received and report promptly, in writing to the Engineer, any shortage or injury discovered. The erection Contractor shall be responsible for the loss of any material furnished by the Department or another Contractor after delivery and acceptance at the job-site, or for any damage to such material during job-site storage or erection.

(d) Falsework. The falsework shall be properly designed, constructed and maintained for the required loads. The Contractor shall prepare and submit falsework plans for the Engineer's review unless waived by the Engineer. Submission of the falsework plans shall not relieve the Contractor of any responsibility for the adequacy of the design or evaluating site conditions.

(e) Methods and Equipment. Before starting work, the Contractor shall submit an erection plan to the Engineer detailing the proposed methods of erection and the amount, location(s) and type(s) of equipment to be used. This plan shall be subject to the subject to the approval of the Engineer, but this approval shall not relieve the Contractor of the responsibility for the safety and adequacy of the method and equipment or from carrying out the work in full.

(f) Bearings and Anchorage. Fixed and expansion bearings on masonry shall be set level and not be placed upon areas that are improperly finished, damaged or irregular. The concrete under each bearing shall be finished smooth and level, within 3 mm (1/8 in.) of the specified elevation before the bearings are placed.

Leveling plates, pads, and/or adjustment shims shall be placed beneath the masonry bearing plates or castings. The Contractor shall drill the holes and install the anchor bolts, except where bolts are built into the masonry. Before installing anchor bolts with epoxy, holes in the masonry shall have depths and diameters verified so the required embedment will be obtained without exceeding the volume the capsule can fill. Holes shall be kept dry to prevent the formation of ice and shall be blown clean prior to installing the anchor bolts.

The location of anchor bolts for expansion bearings shall correspond with the temperature at the time of erection. The nuts on anchor bolts through moving parts at expansion bearings shall be adjusted to provide clearance for the expected movement of the span and either a lock nut or a standard nut and half-thickness jam nut shall be provided to maintain adequate clearance. After anchor bolts are installed, the upper end shall be checked to verify proper embedment. Anchor bolt lengths should leave the exposed end projecting between 12 mm (1/2 in.) and 50 mm (2 in.) above the top of the nut. Nuts for anchor bolts in non-moving elements shall be installed snug tight by a few impacts of an impact wrench or the full force of a worker using an ordinary spud wrench.

Bearing plates to be cast into concrete superstructures shall be secured in the proper position, and all wedges or blocking used to position expansion bearings shall be removed as soon as practicable after the concrete is placed.

The position of expansion bearings on vertically cantilevered abutments shall be adjusted so that anticipated forward movement if the bridge seat will center the line of bearing on the bearing plates. When the plans show expansion bearings off-center, in anticipation of such movement in the substructure, the predicted movement may be adjusted by the Engineer at the time of erection to conform to existing conditions. When bearings provide for the expansion and contraction of a length of superstructure greater than 30 m (100 ft), the temperature at the time of erection shall also be taken into account so that the line of bearing will be at the desired location at a temperature of 10ºC (50ºF).

All side retainers shall be secured in place prior to forming the bridge floor.

(g) Straightening Bent Material. The straightening of plates, angles, and other shapes and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fracture or additional injury. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by the careful planned and supervised application of a limited amount of localized heat, under rigidly controlled procedures. Procedures using heat, with or without external restraints (jacks, come-alongs), shall be detailed to include heat patterns and locations, maximum temperatures, monitoring methods, restraint locations and calculations of restraint forces.

Before beginning any work , these shall be submitted and received for the approval of the Engineer. For AASHTO M 270M (270) Grades 485W, 690 or 690W (70W, 100, or 100W) steels, the temperature shall not exceed 575 ºC (1050 ºF), and for other steels, the temperature of the heated area shall not exceed 620 ºC (1150 ºF) as verified by temperature indicating crayons, infrared or bimetal thermometers. Parts to be heat straightened shall be substantially free of stress from external forces, except the preplanned restraints in the Engineer-approved proposal. Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected, and any evidence of fracture shall be immediately reported to the Engineer.

(h) Assembling Steel. The parts shall be accurately assembled as shown on the plans and approved erection drawings. Match marks shall be followed and beams or girders supported to provide the top of beam/web elevations shown on contract plans (without steel dead load deflection) until field splices are pinned and partially bolted.

Assembly methods shall not distort, break or otherwise damage permanent material. Bearing surfaces and surfaces to be in permanent contact shall be cleaned of foreign material before the members are assembled. Detailed truss spans erection procedures shall be submitted for the Engineer's approval. These shall include blocking and falsework plans, assembly sequence and bolting methods for chords, floor beams, stringers and bracing installation.

Bolted field splices in continuous beams or girders shall not be torqued until the entire continuous length is in place on the substructure. During erection, splices and field connections shall have 1/4 of the holes filled with finger-tight bolts and 1/4 with cylindrical erection pins. Bolt tightening shall not commence until all erection pins at a splice have been removed and all holes are filled with finger-tight bolts. Bolt tightening shall be according to Article 505.04(f). Temporary fitting-up bolts shall be the same diameter as the specified bolts, and cylindrical erection pins shall be mm (1/32 in.) larger.

(i) Field Bolting. High-strength bolts shall be tested and installed according o Article 505.04(f). Drifting shall draw the parts into position but not enlarge the holes or distort the metal.

(j) Other Bolted Connections. In connections, where bolts or turned bolts are used, the bolts shall be brought to snug tight and loosening shall be prevented by either burring the threads at the face of the nut with a pointed tool or other mechanical means, including lockwashers and self locking nuts.

(k) Pin Connections. Pilot and driving nuts shall be used if required for driving pins. Pins shall be installed so that the members will take full bearing on them. Pin nuts shall be tightened sufficiently to limit lateral separation of material to 3 mm (1/8 in.) or that detailed by the contract plans, but not enough to clamp material and restrict rotation. Pins shall be double nutted with jam nuts or have other provisions to prevent loosening of single nuts under normal service conditions, subject to approval by the Engineer.

(l) Misfits. The correction of misfits involving minor field corrections will be considered a part of the erection. Minor field corrections include grinding corners, burrs, or other small areas, removing less than 3 mm (1/8 mm) of material, or reaming of less than 5 percent of holes. Plates shall either be held tightly together during reaming or disassembled for cleaning. Any error in the shop fabrication or permanent deformation resulting from handling and transportation, which prevents the proper assembling and fitting up of parts by the use of drift pins, or by minor field corrections shall be reported immediately to the Engineer. Any proposed method of correction must be approved by the Engineer , and the correction shall be made in the Engineer's presence. If the contract provides for complete fabrication and

erection, the Contractor shall be responsible for all misfits, errors, and juries and shall make the necessary corrections and replacements. If the contract provides for complete fabrication of the steel, the Contractor performing the fabrication shall be responsible for all errors in fabrication. The Engineer will determine: what corrections are considered to be of a minor nature and are included as part of the erection work; what damage or loss is the responsibility of the erection Contractor; and which problems are to be considered errors is fabrication, to be remedied at the expense of the Contractor responsible for the fabrication. Damage occurring during transportation shall be corrected at the expense of the responsible Contractor.

(m) Stud Shear Connectors. Stud shear connectors shall be furnished as a single unit and of a design suitable for end-welding to steel with automatically timed stud welding equipment. Stud shear connectors that are to be welded to the top flanges of beams or girders shall be placed after the steel has been erected and suitable scaffolding or the deck forming has been provided so the hazard due to stud projections is at a minimum. Studs that are to be welded to expansion guards, bearing plates or other locations not posing a hazard may be placed in the shop.

If flux-retaining caps are used, the steel for the caps shall be of a low carbon grade suitable for welding and shall comply with ASTM A 109M (A 109). Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects.

Finish shall be as produced by cold drawing, cold rolling or machining. The manufacturer shall certify that the studs satisfy the requirements of this Section. Certified copies of in-plant quality control test reports shall be furnished to the Engineer upon request. An arc shield (ferrule) of heat-resistant ceramic or other suitable material shall be furnished with each stud. The material shall not be detrimental to the welds or cause excessive slag and shall have sufficient strength so as not to crumble or break due to thermal structural shock before the weld is completed. Flux for welding shall be furnished with each stud, either attached to the end of the stud or combined with the arc shield for automatic application in the welding operation.

(1) Power Source. Stud shear connections shall be end welded with automatically timed stud welding equipment connected to a suitable power source. If two or more stud welding guns are to be operated from the same power source, they shall be interlocked so that only one gun can operate at a timer and so that the power source has fully recovered from making one weld before another weld is started.

Studs may be welded using two or more welding generators in parallel or by use of a battery operated source to supply the necessary amperage.

(2) Preparation and Welding. At the time of welding, the studs shall be free of any rust, rust pits, scale oil or deleterious matter. The surface to

receive the stud shall be free from mill scale and heavy rust. Paint, galvanizing and oil are contaminants and shall be removed.

Welding shall not be done when the base metal temperature is below –17 ºC (0 ºF), or when the surface is wet. If it becomes necessary to weld the studs when the temperature of the base metal is below –17 ºC (0 ºF), base metal shall be preheated and maintained above 0 ºC (32 ºF) during the welding operation.

While in operation, the welding gun shall be held in position without movement until the weld has solidified.

Longitudinal and lateral spacings of studs with respect to each other and to edges of beam or girder flanges shall not vary more than 12 mm (1/2 in.) from the dimensions shown on the plans except that a variation of 25 mm (1 in.) will be permitted where required to avoid obstruction with other attachments on the beam. The minimum distance from the edge of a stud shank to the edge of a beam or plate shall be 25 mm (1 in.).

(3) Inspection and Field Bend Tests. The first two studs welded on each beam or girder, after being allowed to cool, shall be bent 45 degrees by striking the stud with a hammer. If failure occurs in the weld of either stud, the procedure shall be corrected and 2 successive studs shall be successfully welded and tested before any more studs are welded to the beam or girder. This bend check shall also be made at the start of each day of the work, when the welding has been interrupted for an hour or more, when changing grounds, when changing weld settings or when changing cable loop due to arc blow (arc not going vertically from center stud to flange). In any case, no more than 500 studs shall be welded to a beam or girder without the welds being field bend tested according to the foregoing procedure. These bend tests shall be made by the operator and left in the bent position for inspection by the Engineer. All such studs that show no sign of failure as determined by the Engineer shall be left in the bent position. When 22 mm (7/8 in.) studs are welded, bend tests will be performed after every 250 studs. If due to low temperatures, preheating of the base metal has been utilized in preparation for automatic welding of studs to the beams or girders, the operator shall hammer bend to 45 degrees from the vertical two studs in each 100 welded in addition to the first two studs welded on each beam or girder. The studs shall be left in the bent position for examination by the Engineer.

Studs on which a full 360 degrees weld has not been obtained may, at the option of the Contractor, be repaired by adding a 8 mm (5/16 in.) fillet weld in place of the lack of weld, using the shielded metal-arc (SMAW) process with low hydrogen welding electrodes. The repair weld shall extend at least 10 mm (3/8 in.) beyond each end of the discontinuity being repaired. The minimum preheat (flange and stud temperature) for SMAW repair welds is 20ºC (70ºF). The Engineer will bend test questionable studs as follows: Using a heavy hammer the Engineer will strike the stud to bend in the direction opposite to the weld

deficiency until the shank is bent 15 degrees from the vertical (about 25 mm (1 in.) deflection). Then reversing, direction, the stud will be driven back into the vertical position. If there is no visual distress evident in the weld, it will be considered satisfactory.

In addition to the bend tests accomplished by the operator to the satisfaction of the Engineer and the bend tests made by the Engineer, the Engineer will check approximately one percent of the studs at random by striking the stud and bending to an angle of 45 degrees with the vertical. The studs shall be left in the bent position.

If a stud fails or it becomes necessary to remove a stud with a defective weld, the vacated area of the beam or girder flange shall be ground smooth and flush, or in case of a pullout of metal, the pocket shall be welded according to Article 505.04(g) using the shielded metal-arc process with low-hydrogen electrodes and then ground flush. The new stud shall be placed in the dimensional location as the defective stud it replaces.

If the Engineer notes a reduction of the height of the studs as they are welded, the work shall be stopped immediately and not resumed until the cause has been corrected. If the Engineer determines that the shear connectors are not satisfactory by inspection and testing during the progress of the work, the Contractor shall, at his/her own expense, replace all defective studs and make necessary changes in the welding procedure or welding equipment to secure satisfactory results.

(n) Field Welding and Cutting. Field welding shall conform to Article 505.04(q) and all field thermal (flame or plasma) cutting shall conform to Article 505.04(k). No field welding shall be done on main, load carrying members unless specified by the contract plans or with the written permission of the Engineer. The use of thermal cutting in other areas will be permitted only when specified by the contract plans or authorized by the Engineer, and shall be subject to the Engineer's inspection. No thermal cutting equipment shall be permitted on the structure except when in use according to the above requirements.

(o) Construction Loads. Equipment for pulling falsework or other piles, for erecting adjacent structures, or for other tasks not directly related to construction of the structure shall not be operated upon or attached to any portion of the new structure without the written approval of the Engineer.

505.09 Work Under Separate Contracts. When the fabrication, erection, and painting of structural steel, construction of concrete decks, and other collateral work on a structure are accomplished under separate contracts, the following shall apply.

(a) Storing and Protection of Structural Steel. When the fabrication, erection and painting of structural steel is accomplished under separate contracts, the fabrication Contractor shall be responsible for storing and protecting all fabricated structural steel up to 45 calendar days after completion dates, delivery dates or number of working days specified in the fabrication

contract. All storage costs incurred by the fabrication Contractor during this 45 day period shall be borne by the fabrication Contractor.

(b) Shipping of Structural Steel to Jobsite. The erection Contractor shall provide the fabrication Contractor and the Engineer with a schedule for shipping the structural steel to the jobsite within 30 calendar days after the execution of the erection contract. This schedule shall specify the order items are to be received and their orientation for delivery, and must meet the approval of the Engineer. The erection Contractor will be responsible for receiving, unloading storing and protecting the structural steel in accordance with this schedule. If the erection Contractor elects to change this schedule, the erection Contractor shall be responsible for coordinating the change with the Fabrication Contractor and for all costs and time delays associated with such changes.

Delivery of the structural steel to the jobsite shall be the responsibility of the Fabrication Contractor. The mode of delivery shall be the option of the Fabrication Contractor. Delivery shall be limited to the hours between 8:00 a.m. and 5:00 p.m. on weekdays only, excluding any observed holidays, unless otherwise approved by the Engineer. The Erection Contractor shall be responsible for coordination of movement of the structural steel within the contract limits and shall be responsible for all demurrage charges, At the erection Contractor's option and expense, steel may be requested at times other than the stated time.

(c) Installation of Minor Items. Minor items of fabricated steel that cannot be completely installed until either final adjustments are made or the completion of subsequent contracts, shall be delivered and partially erected or stored as directed by the Engineer. These items shall be installed or adjusted, as required, by the Contractor performing the subsequent work.

505.10 Field Painting. Steel structures shall be cleaned and field painted according to Articles 506.03 and 506.05.

505.11 Reserved.

505.12 Method of Measurement. All structural steel shown on the plans will be included for payment unless it is specifically included with a separate pay item. All other structure items, unless they are included with separate pay items or specified as included into other items, will be included as structural steel, and the weight will be calculated based upon their actual mass (density).

The Contractor performing the erection shall furnish the erection bolts and pins, and also pilot and driving nuts when required. The Contractor performing the fabrication shall furnish all fasteners, washers, shipping bolt and fitting-up diaphragms when required.

When minor items of structural steel are specified for payment by weight, the weight used will be the measured mass (weight) of the fabricated structural steel furnished, No measurement will be made or allowed for the mass (weight) of field weld material. The structural steel will be measured in kilograms (pounds) using the approved shipping mass (weight) or by measuring on approved platform scales.

When the plan quantities of minor items of structural steel, such as expansion dams on concrete bridges or miscellaneous steel for the repair of existing structures, is approximately 4500 kg (10,000 lb) or less, the method of measurement for payment will be in accordance with Article 202.07(a) unless a weigh ticket is provided.

505.13 Basis of Payment. Structural steel and other material included in the scope of this item, furnished and erected complete in place, according to the specifications, and accepted, will be paid for at the lump sum price for FURNISHING AND ERECTING STRUCTURAL STEEL, which price shall be payment in full for all materials and for fabrication, shop cleaning and painting, transportation, and erection. Field painting shall also be included unless otherwise provided in the contract.

Fabricated structural steel and other material included in the scope of this item, furnished, delivered, and accepted, will be paid for at the lump sum price for FURNISHING STRUCTURAL STEEL, which price shall be payment in full for all materials, and for fabrication, shop cleaning and painting, and delivery F.O.B. to the unloading point specified.

Storage and care of the fabricated steel by the fabrication contractor beyond the specified storage period, will be paid for at the contract unit price per calendar day for STORAGE OF STRUCTURAL STEEL if a pay item is provided for in the contract, or will be paid for according to Article 109.04 if a pay item is not provided in the contract.

Structural steel and other material fabricated under this item erected according to the requirements of the specifications, and accepted, will be paid for at the lump sum price for ERECTING STRUCTURAL STEEL, which price will be payment in full for unloading, transporting from the unloading point to the bridge site, erection of the fabricated structural steel, and the appropriate application of paint for spot painting bolt heads, field welds and abrasions to the shop coat of paint. This will also be payment in full for furnishing and for the application of the field coats of paint unless otherwise provided in the contract.

If alterations or deductions to the work specified in the aforementioned lump sum items are ordered by the Engineer, the Contractor shall accept payment for any increase or decrease in the amount of structural steel and other materials according to Article 104.02(a). The unit price used for the adjusted work will be determined by dividing the lump sum price bid for the item by the Engineer's calculated weight as shown on the contract plans. No adjustment in this plan weight will be allowed in calculation of the unit price for the adjusted work. Mass (Weight) in kilograms (pounds) for the increased or decreased amounts of structural metals ordered by the Engineer amounts to a change exceeding 0.5 percent of the Engineer's calculated weight as shown on the contract plans or 1360kg (3000 lb), whichever is larger, the unit price used for the increased or decreased amount of structural steel shall be agreed upon by the Contractor and Engineer.

When specified, minor items of structural steel and other material included in the scope of this time, furnished and erected complete in-place, according to the specifications, and accepted, will be paid for at the contract unit price per kilogram (pound) for FURNISHING AND ERECTING STRUCTURAL STEEL, which price shall be payment in full for all materials and for fabrication, shop cleaning and painting, transportation and erection. Field painting shall also be included unless otherwise provided in the contract.

Stud shear connectors that are to be field welded to the top flanges of beams or girders, furnished and installed according to the specifications, and accepted, will be paid for at the contract unit price each for STUD SHEAR CONNECTORS.

SECTION 506. CLEANING AND PAINTING METAL STRUCTURES

506.01 Description. This work shall consist of the cleaning and preparation of steel surfaces; the furnishing, application and protection of the paint coatings; and incidental work on new and existing steel structures.

506.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000- Materials:

Item	Article/Section
(a) Paint Materials and Mixed Paints	1008.01-1008.23
(b) High Strength Steel Bolts, Nuts and Washers	1006.08

CONSTRUCTION REQUIREMENTS

506.03 Cleaning New Structures. After fabrication, accessible surfaces of all steel except bolts, stainless steel, sliding surfaces and items to be hot dip galvanized shall be blast cleaned in the shop after removal of dirt, oil or grease and other foreign substances according to the requirements of the Steel Structures Paining Council (SSPC) Surface Preparation Specification SP 1 for Solvent Cleaning. All outside corners to be shop painted shall be free of abrupt irregularities and dull to the touch prior to blast cleaning. Small areas may be cleaned according to SSPC Surface Preparation Specification SP 11 for Power Tool Cleaning to Bare Metal. Fins, burrs, thermal cutting residue, abrupt deformities, sharpness (corner more acute than a 1 mm (1/32 in.) radius), and other impediments to safe handling or a uniform coating application and performance shall be corrected by grinding and/or other Engineer-approved methods before final blasting or galvanizing. Blast cleaning of areas to be shop painted shall be accomplished according to the requirements of the SSPC Surface Preparation Specification SP 10 for Near White Blast Cleaning. Areas to be blast cleaned but not shop primed shall satisfy the requirements of SSPC Surface Preparation Specification SP 6 for Commercial Blast Cleaning. Diaphragms and/or cross frames shall be cleaned as required for the main members at the same location.

All surfaces to be shop primed shall have an anchor profile of 25 µm to 65 µm (1 to 2.5 mils).

506.04 Shop Painting New Structures. Before painting, all blast products shall be removed from the surfaces, and the cleaning shall be approved by the Engineer. The blast-cleaned surfaces to be painted shall be given a prime coat within 24 hours after cleaning, unless otherwise authorized by the Engineer. The surface shall be primed before any rust forms.

At the Contractor's option, hot-dip galvanizing may be substituted for shop priming of bearings, typical cross frames or diaphragms on non-curved structures,

expansion joint assemblies and other elements not carrying calculated stress. Galvanized surfaces which shall have concrete poured against them shall be chemically passivated or otherwise protected by a method approved by the Engineer. Galvanized bearings for exterior members and elements readily visible after erection shall be prepared for field painting, but galvanized items obscured from public view will not require field painting. The Contractor shall submit a proposal for substituting galvanizing to the Engineer, showing items to be field painted, applicable provisions of AASHTO M111 (ASTM A123), drain/vent holes and any other necessary modifications. There shall be no change in the contract cost if substituting galvanizing for shop priming. Unless galvanizing in lieu of painting, diaphragms and/or cross frames shall be shop and field coated based upon the requirements of the main members at the same location.

The fabricated steel shall not be loaded for shipment to the job-site until: the shop paint is cured; the steel and coating has been inspected and approved by the Engineer; and at least 24 hours after application of paint. No painting shall be done after the material has been loaded for shipment.

The shop painting of steel structures shall conform to the following requirements:

(a) Paint. The paint for the shop coat shall be the inorganic zinc-rich primer according to Article 1008.22. The paint shall be stored at temperatures between 5 ºC (40 ºF) and 43 ºC (110 ºF) or the manufacturer's recommended limits, whichever are more restrictive. A permanent, automated record of storage temperatures shall be maintained and be available for the Engineer's review. Coatings stored at temperatures outside the above limits will be rejected.

(b) Mixing of Paint. The paint shall be thoroughly mixed with a power mixer before being applied and the pigments shall be kept in suspension. Records shall be maintained for every batch or kit of primer, showing when the activator was added to the primer, when the last of the primer was either applied or discarded, and what items were coated with primer. The manufacturer's recommended pot life times shall not be exceeded, and primer applied after that limit shall be removed. Inorganic zinc-rich primer, after initial mixing, shall be strained through a metal screen not coarser than 600 µm (30 mesh) or finer than 250 µm (60 mesh), before application. Small quantities may be withdrawn from the mixed primer and applied by brush or dauber for minor touch-up of thin primer, stiffener snipes and other areas inaccessible for spraying. Pit life and dry film thickness limits shall apply to brush or dauber application.

Thinning will be permitted when required for proper application. The type of thinner used and the amount used shall be as recommended by the paint manufacturer for the ambivalent conditions. Any thinner additions (quantity and time) shall be documented on the record for each batch of primer

(c) Weather Conditions. Primer shall be applied when the temperature of the metal and the air are above 0 ºC (32 ºF) and within the limits specified by the coating manufacturer's product data sheet, and when conditions are otherwise satisfactory for such work, including an air speed less than 8 km/hr (5 mph), a temperature more than 3 ºC (5 ºF) above dew point, and

adequate light and ventilation. The surface of the steel shall be dry when the paint is applied. The relative humidity and ambient temperature ranges specified by the coating manufacturer for primer application shall be maintained in the paint area and areas where steel is stored for at least ten hours after painting is complete. If the relative humidity cannot be maintained above the manufacturer's recommended lower limit due to ambient conditions, alternate methods of ensuring proper cure may be proposed by the Contractor, accompanied by supporting recommendations from the coating manufacturer, for the Engineer's consideration. Documented records correlating the items primed, temperatures of paint and material during application, and the ambient temperature and relative humidity for painting and storage areas shall be maintained by the painting facility.

(d) Application. Paints shall be applied by wither airless or conventional spray methods, except areas inaccessible to spray and small touch-up areas may be painted by brush or dauber. When inorganic zinc-rich primer is being spray applied, the material shall be kept under constant agitation with a power mixer to avoid settling. The applicable recommendations of the coating and spray equipment manufacturers as well as those of the Steel Structures Painting Council for Good Painting Practice shall be followed for all shop painting.

The coating shall be applied to produce a smooth, uniform coating with an average dry-film thickness of at least 75 µ (3.0 mils) at any location. The minimum dry-film thickness of an inorganic zinc-rich prime coat measured at any spot shall be at least 65 µm (2.5 mils), except as otherwise specified for contact surfaces of high-strength bolted connections. If the paint coating is too thin or if portions of the steel are not coated completely, the deficient portions shall be prepared and repainted according to the coating manufacturer's recommendations for surface preparation, thinning and technique. The maximum dry film thickness (DFT) shall be 150 µm (6.0 mils) for a single coat and 200 µm (8.0 mils) for multiple coats. DFT in excess of these limits may be reduced by methods approved by the Engineer or the coating may be removed and replaced. Alternatively, the Contractor and coating manufacturer may propose verification tests that prove the integrity and acceptability of the heavier DFT to the Engineer. If the Engineer accepts the evaluation methods and the areas of excessive DFT satisfy testing, they may remain. All such testing shall be at the Contractor's expense, and the Contractor remains responsible for the performance of the primer until final acceptance of the field coats on those areas.

(e) Removal of Unsatisfactory Paint. If all or a portion of the paint coat shows significant or widespread defects, evidence of having been applied under unfavorable conditions, or poor workmanship, the Engineer may order it removed and steel cleaned and repainted. Where "mud cracking" occurs in inorganic zinc-rich primer, it shall be removed to soundly bonded paint and re-coated if necessary for adequate DFT. Areas adjacent to the removal of unsatisfactory paint shall be feathered to provide a smooth transition between originally and re-applied paint.

(f) Contact and Inaccessible Surfaces. Surfaces in contact at shop-welded or shop-bolted joints need not be painted unless specified, but shall be free of heavy or loose rust and scale, non-adherent paint and other foreign material. Unpainted shop bolted connections joining elements which each require Charpy V-notch (CVN) tested material shall be cleaned to the requirements of SSPC SP6, Commercial Blast Cleaning. Surfaces not in contact, but which will be inaccessible after assembly and erection, shall be shop primed.

For painted areas, contact surfaces of field bolted connections joining elements which each require CVN tested material shall receive one shop coat of primer with a dry-film thickness from 25 to 125 µm (1.0 to 5.0 mils).

(g) Surfaces in Contact with Concrete. Top surfaces of painted beams and girders shall be given one shop coat of primer, except that portions where stud shear connectors are field installed shall not be painted. Unless hot dip galvanized, all portions of expansion guards (except anchor studs or bars), that are to be in contact with or partially embedded in concrete, shall be shop primed. Steel that is to be completely embedded in concrete shall not require painting except when specified.

(h) Machine-finished Surfaces. Machine-filled surfaces of pins, pin holes, or other sliding surfaces except stainless steel, shall be coated as soon as practicable after being approved, with lacquer or an anti-rust compound. When anti-rust compound is used, it shall be removed at the time of erection and a coating of a suitable lubricant approved by the Engineer shall be provided and applied by the Erection Contractor before installation.

(i) Bearing Surfaces. All surfaces of rockers, bolsters, masonry (base) plates and shims of fills placed under masonry plates shall be given one coat of primer. Sole (top bearing) plates welded or bolted to members shall receive the same treatment as the member at that location.

(j) Connectors. For areas that will be shop and/or field painted, all high-strength bolts and other connectors, including nuts and washers, installed in the shop or field shall be zinc-coated according to Article 1006.08.

(k) Erection Marks. Erection match marks and member piece marks must be legible when delivered to the jobsite. Contrasting paint may be used on areas that have received shop primer to identify locations of stamped marks or to duplicate their information. The paint used must be the same as, or compatible with, the field topcoat. Paint marks used on unpainted steel must be in locations not readily visible on the finished structure, such as the outside face of exterior members or the underside of bottom flanges. Removing such marks in areas readily visible after erection is included in the erection Contractor's responsibilities.

506.05 Field Painting New Structures. The requirements of Article 506.04, paragraphs (b) to (e), inclusive, shall also pertain when applying intermediate and final coats of paint on new steel, hereinafter referred to as "field painting" whether in a field or shop environment.

The Contractor shall protect pedestrian, vehicular, watercraft, or other traffic upon or underneath the structure and also all portions of the structure against damage or disfigurement by paint. When painting over waterways, the Contractor shall implement such controls as are necessary to avoid paint spills into the water or depositing paint films on the water during spraying operations.

Field painting shall consist of spot painting and application of paint coatings required. Paint may be applied by spray or with brushes as specified in Article 506.04(d), Airless equipment shall be used when spray painting is done in the field. In addition, the use of rollers will be permitted in the application of paint coatings to flat surfaces, provided satisfactory results are obtained. Only brushes or rollers shall be used when spray painting is prohibited by the Special Provisions. If the structure includes a concrete deck, field painting at the job site shall be done after the deck is poured and the forms have been removed.

Before the application of the first field coat, the prime coat shall be cleaned of all dirt, oil and other foreign substances by high pressure water. Concrete spills, tar and other adherent foreign material may require removal methods that damage the primer, but the steel must not be injured. Rust staining due to unpainted top flanges need not be removed. Also prior to the first field coat, prime coat damage, field welds, bare steel that must be field painted, any rust that has developed in shop primed areas shall be power tool cleaned to SP 11 or blast cleaned to SP 6, and surfaces shall be dry.

When a structure has been cleaned to the satisfaction of the Engineer, it shall be spot painted in areas specified to receive field paint and/or where the hot-dip galvanizing coating has been damaged. The spot painting shall consist of the application of one coat of high build aluminum epoxy mastic paint applied on the exposed portions of field bolts, damaged galvanizing and all areas noted in the last sentence of the preceding paragraph. A compatible coating produced by the manufacturer may be used in lieu of the aluminum epoxy mastic if approved by the Engineer. Stainless steel surfaces shall not be painted.

The dry film thickness of the aluminum epoxy mastic shall be 125 to 175 µm (5.0 to 7.0 mils) and it shall be applied when the surface is dry and both the steel and coating temperatures are within the manufacturer's recommended range. The spot painted areas shall be kept within the manufacturer's recommended temperature range and protected from moisture and contaminants until full cure has been verified. Spot painting shall be done when dirt or other material from the cleaning operations will not fall or blow on the spot coat.

The sequence of the work shall permit the prime coat to fully cure and/or the intermediate coat to satisfy recoating requirements before the next coat is applied. In no case shall paint be applied until the previous coat has been inspected by the Engineer and its condition has been verified by the appropriate tests.

Except as provided herein, field painting shall be done after the erection is completed. Surfaces that require field paint but would be inaccessible after the erection is completed shall be painted as approved by the Engineer during either fabrication or erection or at the job site prior to installation.

Surfaces that will have concrete poured against them or that shall be in contact within high-strength bolted connections shall receive no field paint.

(a) The number of coats, colors, and types shall be as specified in the contract.

(b) Machine-finished Surfaces. Except for stainless steel which shall not be painted, machine-finished surfaces, and the ends, threaded parts and nuts of pins exposed after erection shall be cleaned according to SSPC SP 1, Solvent Cleaning, be painted with one coat of the paint used for spot painting, and then be painted with the paint specified for field painting the structure

(c) Work Under Separate Contracts. All field cleaning and field painting of new work shall be included as part of the contract that includes the erection of the steel. When complete field painting is not included in the contract that includes the erection, the spot cleaning and painting of damaged coatings on newly erected work and applying one coat of the field paint to applicable surfaces that will be inaccessible after erection shall be included under the contract that included the erection. Field painting under a contract that does not include the erection shall include the cleaning and spot preparation necessary at the time the work is performed, and the additional spot and field paint coatings required.

(d) Inspection. The Contractor shall provide the Engineer adequate access for the inspection during all stages of work performed. The Contractor shall use a compatible paint with contrasting color to stencil the date of painting and the paint type code from the Structural Information and Procedure Manual on the surface of the final field coat. The letters shall be capitals, not less than 50 mm (2 in.) and not more than 75 mm (3 in.) in height. The stencil shall contain the word “Painted” and shall show the month and year in which the painting was completed followed by the proper paint type code. This shall be stenciled on the top surface of a truss end post or arch rib rear the top of the right side railing, or on the outside face of the left-side fascia member near each ends of the bridge (at the right end of the structure when viewed from below), or at some equally visible surface designed by the Engineer.

506.06 Method of Measurement. Shop cleaning and painting new structures will not be measured for payment. Field cleaning and painting will not be measured for payment except when performed under a contract that contains a separate pay item for this work.

506.07 Basis of Payment. Cleaning and painting in connection with the fabrication and erection of steel structures will not be paid for separately but shall be considered as included in the contract unit price or prices for furnishing, fabricating and erecting, or installing the material.

The field cleaning and painting of newly erected structural steel under a contract separate from the fabrication and erection will be paid for at the lump sum price for CLEANING AND PAINTING STRUCTURAL STEEL, at the location specified and the field cleaning and painting of steel railings which are fabricated and erected at the contract unit price per meter (foot) will be paid for at the contract unit price per meter

(foot) for PAINTING STEEL RAILING when performed under a contract separate from the erection.

SECTION 507. TIMBER STRUCTURES

507.01 Description. This work shall consist of timber construction required for bridges and appurtenances, where the timber is incorporated in the completed structure. All lumber and timber for erection purposes, such as falsework, forms, sheeting, bracing, etc., shall be furnished by the Contractor at his/her own expense and is not subject to the requirements of this Section.

507.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Timber for Bridges	1007.04
(b) Timber Piling	1007.08
(c) Preservative Treatment	1007.12
(d) Hardware	1006.17
(e) Structural Steel	1006.04
(f) Asphalt Cement, Grade PG52-28, PG58-28 or PG 58-22	1009.01 - 1009.05
(g) Fine Aggregate	1003.03
(h) Paint Materials and Mixed Paints	1008.01 - 1008.23

Structural steel and other metals requiring fabrication shall be fabricated according to Section 505.

CONSTRUCTION REQUIREMENTS

507.03 Storage of Materials. Untreated lumber at the site of the work shall be open-stacked on supports at least 300 mm (12 in.) above the ground and shall be so stacked and stripped as to permit free circulation of air between the tiers and courses. When required by the Engineer, it shall be protected from the weather by suitable covering. Treated timber shall be close-stacked according to Article 1007.12.

507.04 Workmanship. All timber shall be accurately cut and framed to a close fit in such manner that the joints will have even bearing over the entire contact surfaces. Unless otherwise specified, nails and spikes shall be driven just sufficiently to set the heads flush with the surface of the wood. Deep hammer marks in wood surfaces shall be considered evidence of poor workmanship.

507.05 Treated Timber. All cutting, framing and boring of treated timber shall be done before treatment insofar as is practicable.

(a) Handling. Treated timber shall be handled carefully without sudden dropping, bruising, breaking of outer fibers or penetrating the surface with tools. It shall be handled with rope slings. Cant hooks, peaveys, pikes or hooks shall not be used.

(b) Cuts, Abrasions, and Holes. All cuts, abrasions, and holes made after treatment shall be repaired according to Article 1007.12(f). Each coat shall be allowed to dry before the next coat is applied. Any unfilled holes, after being treated with preservative oil, shall be plugged with treated plugs.

(c) Temporary Attachments. Forms or temporary braces may be attached to treated timber with nails or spikes only when approved by the Engineer. Upon their removal, the holes shall be filled by driving galvanized nails or spikes flush with the surface, or by plugging as required for holes.

507.06 Countersinking. Countersinking shall be done wherever smooth faces are required. Recesses formed in treated timber for countersinking shall be treated as required for cuts and abrasions, except as specified for plank floors.

507.07 Hardware. The term Hardware shall include all metal fastenings required for timber connections or for connecting timber to concrete or steel work. The following items will be considered as Hardware: bolts, tie rods, turnbuckles, washers, nuts, drift bolts, steel dowels, nails, spikes and lag screws for timber connections; steel plates used as washers or between timber caps and the tops of piles or timbers; metal timber connectors of various designs; metal shear developers for composite timber and concrete floors; and anchor plates or clips for plank floors and sidewalks. Sheet metal pile coverings and steel traffic treads and their fastenings are not considered as Hardware.

All hardware for treated timber construction, except cast iron O. G. washers and malleable iron washers and timber connectors shall be galvanized.

(a) Rods. Rods connecting only sawed timbers shall be threaded sufficiently at each end to provide tight connections, allowing for permissible variations in dimensions of material. All rods shall extend entirely through the nut at each end and, after being drawn tight, all ends that project more than 25 mm (1 in.) beyond the nut shall be cut off about 13 mm (1/2 in.) beyond the nut.

(b) Bolts. The length specified shall be the length measured under the head. Bolts may be substituted for rods for timber connections where the length of threaded portion provided by the bolt is sufficient. Bolt ends projecting more than 25 mm (1 in.) beyond the nut shall be cut off as specified for rods. Special flat head bolts, or carriage bolts, shall be used for connections horizontally through railings and wheel guard timbers, with the head at the roadway face of the timbers. Machine bolts with square heads and nuts shall be used for other connections.

(c) Lag Screws. Lag screws shall be installed by turning them into place. They may be driven sufficiently to start them into the holes and hold them firmly in place for turning, but shall not be driven beyond the depth that will be occupied by the shank.

(d) Nuts and Washers. Washers shall be used under all nuts and bolt heads that would otherwise come in contact with wood, except under large diameter heads of specially designed flat head bolts. O. G. or malleable iron washers shall be used for all tie rods except where plate washers are called for by the plans, and for all rods and bolts passing through piles

except bolts connecting railing plank to wing piles. Standard wrought washers shall be used at all locations except where washers of other types are required. All nuts shall be standard square nuts. They shall be tightened sufficiently to prevent the rods or bolts from becoming loose during service and, after being tightened, they shall be effectively secured against backing off by burring of the rod or bolt threads, or as otherwise specified or approved by the Engineer.

(e) Nails and Spikes. Nails shall not extend through all material into which they pass except when approved by the Engineer. The size of nails and spikes, when not otherwise shown, shall conform to the following:

Size of Nails			
Actual Thickness of Piece Nailed mm (in.)		Actual Thickness of Piece Nailed to mm (in.)	Size of Nails
41	(1 5/8)	41 (1 5/8)	10d
41	(1 5/8)	50 (2)	16d
41	(1 5/8)	66 (2 5/8) or more	20d
50	(2)	50 (2)	16d
50	(2)	66 (2 5/8) or more	20d
66	(2 5/8)	66 or 75 (2 5/8 or 3)	40d
66	(2 5/8)	92 (3 5/8) or more	60d
75	(3)	75 (3)	50d
75	(3)	92 (3 5/8) or more	60d
92	(3 5/8)	92 Spikes (3 5/8)	
100	(4)	92 or more (3 5/8)	178 mm (7 in.) spikes

507.08 Holes for Bolts, Dowels, Rods and Lag Screws. Holes for round drift bolts and dowels shall be bored with a bit 2 mm (1/16 in.) less in diameter than the bolt or dowel to be used. The diameter of holes for square drift bolts or dowels shall be equal to the least dimension of the bolt or dowels. Holes for bolts shall be bored with a bit of the same diameter as the bolt. Holes for rods shall be bored with a bit 2 mm (1/16 in.) greater in diameter than the rod. Holes for lag screws shall be bored with a bit not larger than the body of the screw at the root of the thread. If required to prevent splitting, the hole for the shank shall be bored the same diameter as the shank. The depth of holes for lag screws shall be approximately 25 mm (1 in.) less than the length under the head.

507.09 Pile Bents and Abutments. All work involving piles shall conform to Section 512. Cut-offs shall be made accurately to ensure perfect bearing between the cap and piles, or good alignment of the tops of wing piles. No shimming between pile tops and caps will be permitted except to provide for adjustment of not more than 25 mm (1 in.) required on account of errors in cut-off. The shim for this purpose shall consist of a single square steel plate of the proper thickness, having the same width as the cap, punched 2 mm (1/16 in.) larger than the drift bolt, and shall be furnished and placed at the sole expense of the Contractor. The piles for any one bent or line shall be selected carefully as to size, to avoid undue bending or distortion of the bracing or backing timbers. Care shall be exercised in the distribution of piles of varying sizes to secure the required strength and rigidity throughout the structure.

507.10 Caps. Timber caps shall be placed, with ends aligned, in a manner to secure an even and uniform bearing on the tops of the supporting posts or piles. They shall be secured by a drift bolt not less than 20 mm (3/4 in.) in diameter, extending at least 225 mm (9 in.) into each post or pile. The drift bolt shall be as near the center of the post or pile as possible without interfering with rods passing through the post or pile near the cap. Caps shall not be spliced except as provided by the plans.

507.11 Backing Plank. Backing plank shall be placed so that exposed ends form a straight line. They shall be fastened to each pile and nailing strip with at least 2 nails or spikes. Splices in backing plank shall be made at the center of a pile and splices in adjoining lines or plank shall be staggered. Backing plank for wings shall be placed so that the top of the top plank will be at the proper elevation.

507.12 Stringers. Timber stringers shall be placed in position so that the floor will have an even bearing on all stringers and so that any knots near edges will be in the top portions of the stringers. Outside stringers may have butt joints, centered over caps or floor beams, but interior stringers shall be lapped to take bearing over the full width of the cap or floor beams at each end. Stringers shall be toenailed to caps and intermediate stringers of adjoining spans shall be spiked together where they lap.

Cross-bridging between stringers shall be neatly and accurately framed, and securely toenailed with at least two nails in each end. All cross-bridging members shall have full bearing at each end against the sides of stringers. Unless otherwise specified, 50 mm (2 in.) by 100 mm (4 in.) cross-bridging shall be placed at the center of each span.

507.13 Plank Floors. Unless otherwise shown, the floor planks shall be laid at right angles to centerline of roadway. The planks shall be carefully graded as to thickness and laid so that no two adjacent planks will vary in thickness by more than 2 mm (1/16 in.). When more than one length of plank is required, joints between abutting ends shall be staggered at least 1 m (3 ft) in any two adjacent lines of plank. Ends of planks at the edges of the roadway shall be cut on a straight line parallel with the centerline of the roadway.

When plank floors on steel stringers are to be fastened to nailing strips bolted to the sides of the steel stringers, the top of each nailing strip shall be flush with the top of the beam or channel. A recess of the proper width and depth shall be provided in the top surface of the nailing strip to fit neatly around the projecting flange of the beam or channel. Nailing strips for treated plank floors shall be so recessed before treatment.

In constructing floors of untreated material, the planks shall be laid heart side down with 5 mm (1/4 in.) joints between them for seasoned material and with tight joints for unseasoned material. Treated plank floors shall be laid with tight joints except when the planks are separated by anchor clips used for fastening the planks to steel stringers.

Standard wrought washers shall be used under the heads of all lag screws and under the heads or nuts of all machine bolts used for fastening the floor plank.

Where machine bolts are used for fastening the floor plank, all nuts used shall be locknuts. Heads of all lag screws and bolts in the surface of the floor shall be countersunk so that the tops will be flush with the surface of the plank. Recesses formed for countersinking shall be just large enough to admit the washers and, after the lag screw or bolt is in place, shall be filled with hot pitch.

For laminated or Strip Floors, the strips shall be placed on edge and each strip shall be nailed to the preceding strip at each end with two nails and approximately at 450 mm (18 in.) intervals with nails driven alternately near the top and bottom edges. The nails shall be long enough to pass through two strips and at least halfway through the third strip. If timber stringers or nailing strips are used, every other strip shall be toenailed to every other support. Care shall be taken to have each strip vertical and tight against the preceding one, and bearing evenly on all supports.

507.14 Bituminous Surface Coat. When required, plank floors shall be given a bituminous surface coat. The floor shall be cleaned of foreign materials and the asphalt cement shall be applied at a temperature of from 135 ºC to 175 ºC (275 ºF to 350 ºF) and at a rate of approximately 1 L/sq m (1/4 gal/sq yd) of surface. The plank shall be dry at the time of this application. The entire surface shall then be covered with a thin coating of fine aggregate, sufficient in quantity to take up any free bitumen.

507.15 Steel Traffic Treads. Steel traffic treads shall be not less than 5 mm (3/16 in.) thick, exclusive of the raised portions, not less than 600 mm (24 in.) wide, and the individual sections not more than 4.5 m (15 ft) long. Treads shall have a non-skid surface with alternate projections at right angles to each other. The raised portions shall be formed in the rolling and not by punching or pressing from the under side. Treads shall be punched 11 mm (7/16 in.) for lag screws or bolts. The holes shall be placed not less than 30 mm (1 1/4 in.) nor more than 40 mm (1 1/2 in.) from the edge of the tread. The spacing of holes on both sides of the tread shall be not more than 375 mm (15 in.) and on both ends of each section not more than 150 mm (6 in.). The unit weight of the treads shall be approximately 43 kg/sq m (8 3/4 lb/sq ft).

Before the treads are laid, all high spots and rough spots in the plank floor shall be removed so that the treads will be in contact with the floor for their full length and width. Treads shall be laid in a heavy mop coat of hot asphalt conforming to Article 1009.06, PAF-3. Treads shall be laid with a space of 5 mm (1/4 in.) between adjacent ends and shall be fastened by means of M10 (3/8 in.) galvanized bolts. Where bolts cannot be installed, M10 (3/8 in.) by 75 mm (3 in.) galvanized screws shall be used.

507.16 Wheel Guards and Railings. Wheel guards and railings shall be accurately framed so that they will be true to line and grade. Wheel guards shall be laid in sections not less than 3.6 m (12 ft) long with each splice located approximately over the center of a scupper block. Railing plank shall be untreated timber and shall be painted two coats of white paint. Surfaces in contact with rail posts or piles shall be painted one coat before the railing planks are erected.

507.17 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. The quantity of timber will be computed in cubic meters (foot board measure). Computations of quantity will be based on the nominal commercial widths and thicknesses of the material. The length will be the actual lengths of the various pieces required, measured to the nearest 25 mm (1 in.). The length of each piece with a beveled end will be taken as the overall length of the piece, except that when two or more pieces with beveled ends may be cut economically from a single commercial length, the sum of the lengths will not exceed the commercial length required. The quantity computed for payment will include all splices required by the plans but will not include any allowance for additional splices or waste.

The weight of hardware will be computed in kilograms (pounds) by the Engineer. The weight of rods and plates will be computed from the weights shown in the current edition of the American Institute of Steel Construction Manual, with no deduction for holes and no allowance for overrun. Weights computed from dimensions of material will be based upon a weight of 7850 kg/cu m(490 lb/cu ft) for steel, 7770 kg/cu m (485 lb/cu ft) for wrought iron, and 7200 kg/m^3 (450 lb/cu ft) for cast iron. No additional allowance for loss or waste will be added to the computed weights, but an additional allowance of 3 1/2 percent for galvanizing will be added to weights of all galvanized material computed on the basis of ungalvanized material.

Bituminous surface coat for plank floors will be measured for payment in square meters (square yards).

Steel traffic treads will be measured for payment in square meters (square feet).

507.18 Basis of Payment. All work and materials involved in the construction of timber structures will be paid for at the contract unit prices for the various unit price items of the contract. Treated timber will be paid for at the contract unit price per cubic meter (foot board measure) for TREATED TIMBER. Untreated timber, including any painting required, will be paid for at the contract unit price per cubic meter (foot board measure) for UNTREATED TIMBER. All items classed as hardware will be paid for at the contract unit price per kilogram (pound) for HARDWARE. Bituminous surface coat for plank floors will be paid for at the contract unit price per square meter (square yard) for BITUMINOUS SURFACE COAT. Steel traffic treads, including bolts, lag screws, or other fastenings, will be paid for at the contract unit price per square meter (square foot) for STEEL TRAFFIC TREADS.

SECTION 508. REINFORCEMENT BARS

508.01 Description. This work shall consist of furnishing and placing reinforcement bars.

508.02 Materials. Materials shall meet the requirements of Article 1006.10.

CONSTRUCTION REQUIREMENTS

508.03 Storage and Protection. The reinforcement bars, when delivered on the job, shall be stored above the surface of the ground upon platforms, skids or other supports, and shall be protected from mechanical injury and from deterioration by exposure. When placed in the work, they shall be free from dirt, detrimental scale, paint, oil or other foreign substances. A light coating of rust will not be considered objectionable. For epoxy-coated reinforcement bars, all systems for handling shall have padded contact areas. The bars or bundles shall not be dropped or dragged. Coated bars shall be stored on wooden or padded steel cribbing.

508.04 Cutting and Bending. Reinforcement bars shall be cut and bent at the mill or shop to the shapes shown on the plans before shipment to the work. Bending in the field will not be permitted except to correct errors, damage by handling and shipping, and minor omissions in shop bending.

Epoxy-coated reinforcement bars on skewed bridges and in other locations that are specified to be cut in the field shall be either sawed or sheared but shall not be flame cut. Patching of the bar cuts shall be according to ASTM D 3963 specifications.

508.05 Placing and Securing. All reinforcement bars shall be placed and tied securely at the locations and in the configuration shown on the plans prior to the placement of concrete. Reinforcement bars shall not be placed by sticking or floating into place during or immediately after placement of the concrete.

Bars shall be tied at all intersections except where the center to center dimension is less than 300 mm (1 ft) in each direction, in which case alternate intersections shall be tied. The number of ties as specified shall be doubled for lap splices at the stage construction line of concrete bridge floors when traffic is allowed on the first completed stage during the pouring of the second stage.

Prior to the placement of any concrete, all mortar or other foreign material shall be removed from the reinforcement. Placement of the concrete shall not commence until the Engineer has inspected and approved the reinforcement placement. The Contractor shall correct any misalignment of the reinforcement bars occurring during the placement of the concrete.

The clearances from the face of the form shall be maintained by the use of chairs or other supports approved by the Engineer. Clearance from the bottom of footing shall be maintained by concrete blocks, cement bricks, suspended in place, or other supports system approved by the Engineer. Pebbles, stones, building bricks, and wood blocks shall not be used for bar supports. Bars in the bottom of beams and girders shall be supported by chairs placed on the forms. In beams and girders having two or more layers of bars, the chairs for the upper layer shall rest on the immediate lower layer, top bars in beams and girders shall be supported from the adjacent slab or from the stirrups.

Supports shall be metal or plastic. Metal bar supports shall be made of cold-drawn wire, or other approved material and shall be either epoxy coated, galvanized or plastic tipped. When the rebars are epoxy coated, the metal supports shall be epoxy coated. The supports may be recycled plastic. Supports shall be provided in

sufficient number and spaced to provide the required clearances. All supports shall meet the approval of the Engineer.

Bars in the bottom of concrete bridge floors shall be supported from the forms on continuous type bar supports placed transversely to the bottom bars at a maximum spacing of 1 m (3 ft 3 in.). Bars in the top of concrete bridge floors shall be supported on continuous high chairs placed transverse to the bottom bars of the top mat at a maximum spacing of 900 mm (3 ft). Individual high chairs may be used to support the bars in the top of concrete bridge floors in lieu of continuous high chairs. If individual high chairs are used, they shall be spaced at a maximum of 600 mm (2 ft) by 900 mm (3 ft) centers, or equivalent. The requirements, as herein specified, for supporting bars in concrete bridge floors are minimum requirements only and the Contractor is in no way relieved of the responsibility of providing additional supports as may be required to support the bars firmly in their correct position. When working loads on the bars prior to and during concrete placement includes chutes, pipes or tubes for pumping concrete, or other unusual material or equipment, special consideration shall be given to the need for supplementary bar supports.

In addition to the requirements for tying bars at intersections, as herein specified, the bars in the tops of slabs shall be securely held in place by 3.8 mm (No. 9) wire ties, or other devices fastened to the structural steel, falsework or other structural component at a maximum of 7.6 m (25 ft) longitudinal and 4.5 m (15 ft) transverse spaces. Welding to the structural steel will not be permitted.

Epoxy-coated reinforcement bars shall be tied with plastic or epoxy coated wires or acceptable molded plastic clips. After the bars are in place and immediately before placement of the concrete, the coated bars will be inspected for damage to the coating. Damage caused during shipment of epoxy bars or by installation procedures or both need not be repaired in cases where the damaged area is 5 x 5 mm (1/4 x 1/4 in.) or smaller, and the sum of all damaged areas in each 300 mm (1 ft) length of bar does not exceed two percent of the bar surface area. All damaged areas larger than 160 sq mm (1/4 sq in.) shall be repaired and all bars with total damage greater than 2 percent of bar surface area in any 300 mm (1 ft) length of bar shall be rejected and removed. The total bar surface area covered by patching material shall not exceed 5 percent. Epoxy-coated bars at bonded deck construction joints shall be protected from coating damage during preparation of the joint surfacing for bonding. If sandblasting is used in preparation of the joint area, as allowed in Article 503.09(b), the Contractor shall be required to wrap or otherwise protect the bar coating during the blasting operation.

Prior to the placement of concrete for bridge decks, the clearance for the top mat of reinforcement bars shall be checked. A template shall be attached to the finishing machine or vibrating screed and a dry run shall be made over the entire area of the deck. The template shall be set to 6 mm (1/4 in.) less than the specified clearance to allow for tie wires. Any reinforcement exceeding the allowable tolerance shall be corrected before the start of concrete placement.

508.06 Splicing. Reinforcement bars shall be furnished in the full lengths indicated upon the plans. No splicing of bars, except where indicated on the plans, will be permitted without the written approval of the Engineer. All reinforcement bars specified along a continuous line of bars shall be lapped the specified length and shall be contact spliced and wired together. All lapping reinforcement bars, not

specified along a continuous line and contact spliced, shall be placed a clear distance apart of at least 65 mm (2 1/2 in.) or contact spliced, whichever requires the least adjustment in the bar spacing specified.

Splicing of reinforcement bars by welding will not be allowed.

508.07 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Reinforcement bars and epoxy coated reinforcement bars incorporated in special reinforced pavement designs and in structures will be measured in kilograms (pounds) as computed for the sizes and lengths of bars shown on the plans or authorized by the Engineer. In computing the quantity to be paid for, the quantity of the bars of the cross section shown on the plans, or authorized, will be used. These weights are given in the following table:

Size of Bars Metric	Weight in Kilograms per Meter
No. 10	0.785
No. 15	1.570
No. 20	2.355
No. 25	3.925
No. 30	5.495
No. 35	7.850
No. 45	11.775
No. 55	19.625

Size of Bars	Weight in Pounds per Foot
No. 2	0.167
No. 3	0.376
No. 4	0.668
No. 5	1.043
No. 6	1.502
No. 7	2.044
No. 8	2.670
No. 9	3.400
No. 10	4.303
No. 11	5.313
No. 14S	7.650
No. 18S	13.600

The computed weight will not include the extra metal used when bars larger than those specified are substituted by the Contractor with the permission of the Engineer, the extra metal necessary for splices when bars shorter than

those specified are substituted with the permission of the Engineer, or the weight of any devices used to support or fasten the steel in correct position, the weight of the epoxy coating or the weight of specified test bars.

Tie bars in pavement or between pavement and other new and/or existing pcc appurtenances including all labor and materials required for installation and testing will not be paid for separately, but shall be considered as included in the unit bid price for the portland cement concrete item involved. Dowel bars in load transmission devices for pavement, and marginal bars in pavement, when required, will not be measured for payment. Reinforcement bars required for concrete piles or other reinforced concrete work in structures, where the concrete is not measured for payment in cubic meter (cubic yards), will not be measured for payment, but shall be considered as part of the piles or other complete units that are to be paid for as such. If the weight of the reinforcement per unit of measurement is increased from that shown on the plans, by authority of the Engineer, the additional weight of the steel will be measured for payment.

508.08 Basis of Payment. Reinforcement bars in special reinforced pavement designs and in reinforced concrete structures where the concrete is paid for at a unit price per cubic meter (cubic yard), furnished and incorporated in the work according to the specifications, will be paid for at the contract unit price per kilogram (pound) for REINFORCEMENT BARS or REINFORCEMENT BARS, EPOXY COATED.

SECTION 509. METAL RAILINGS

509.01 Description. This item shall include the furnishing of all materials and the necessary labor to construct and erect the completed railing of the type specified. The line and grade of the railing shall be true to that shown on the plans and not follow any defects in the superstructure. When the bridge is on a grade, railing posts, panels and openings shall be vertical except that posts for low metal railings on concrete parapets shall be normal to the parapet. Tops of railings shall be parallel to grade line.

509.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Structural Steel	1006.04
(b) Paint Materials and Mixed Paints	1008.01 - 1008.23
(c) Steel Pipe	1006.18
(d) Aluminum for Railings	1006.30
(e) Stainless Steel Hardware for Railings	1006.31
(f) Fabric Bearing Pads	1082.01
(g) Steel Posts for Railings	1006.34(a)
(h) Tubular Steel Rail for Railings	1006.34(b)
(i) Steel Shapes and Plates for Railing	1006.34(c)
(j) High-Strength Steel Bolts, Nuts and Washers	1006.08

CONSTRUCTION REQUIREMENTS

509.03 Steel Railings. Steel railings shall be fabricated, inspected, stored and erected according to Section 505 except that galvanized tubular railing and accessories shall be stored according to Article 1006.34. When painting is required, the cleaning and painting shall be according to Section 506. Galvanized railing shall not be painted.

The longitudinal rail members shall be neatly cut to fit at the steel posts as may be required by the plans. All weld areas shall be ground smooth in the shop. The rails shall be straight and true to line, without kinks, bends or warps, and shall be straightened as may be necessary before shipment.

When rail is specified to be painted, shop painting shall consist of one coat of paint.

After erection, the steel railings shall be cleaned to remove dirt, oil, grease or other foreign material.

When rail is specified to be painted, field painting shall consist of spot painting, followed by two complete coats of field paint applied to all accessible surfaces of the steel railings. Spot painting shall consist of one coat of shop paint applied to the heads and nuts of all field bolts, including anchor bolts, and to all areas from which the shop coat of paint has become abraded or otherwise damaged or removed.

509.04 Aluminum Railings. The materials for aluminum railings shall be aluminum alloy conforming to Article 1006.30. Care shall be taken to avoid scratching, denting or other defects that may affect the durability or appearance of the railing.

509.05 Tubular Thrie Beam Retrofit Rail. The Tubular Thrie Beam rail section shall be fabricated by welding two Thrie Beam rail elements according to the details shown on the plans. The Thrie Beam rail section shall conform to the requirements of AASHTO M 180, Type 1, of the class specified.

All structural steel shapes and plates shall conform to AASHTO M270 M Grade 250 (M270 Grade 36) and shall be galvanized after fabrication according to AASHTO M 111 and ASTM A 385.

The Contractor shall load test 5 percent of the epoxy grouted M26 (1 in.) diameter threaded anchor rods in the presence of the Engineer. The equipment and method used shall meet the approval of the Engineer. Pull out load shall be 33 kN (7400 lb) per rod after the epoxy has set. For each anchor that fails the test, 2 more anchors selected by the Engineer, shall be tested. Each anchor that fails shall be reset in epoxy and retested until it passes the test. Epoxy grouting of anchor rods shall be according to the requirements of Section 584.

The standard length for a Tubular Thrie Beam section is 7.5 m (25 ft 0 in.). Posts shall be provided at standard 2.5 m (8 ft 4 in.) centers whenever practical.

Posts shall not be located closer than 375 mm (1 ft 3 in.) to an existing bridge expansion joint or end of bridge.

In the event that standard lengths of Tubular Thrie Beam cannot be longitudinally positioned to meet the requirements, shorter custom fabricated section(s) will be specified. When necessary to use custom length sections of Tubular Thrie Beam, the minimum length shall be 750 m (2 ft 6 in.) with the hole spacing for joints the same as the full length sections.

Three steel shims per post [1 at 3 mm (1/8 in.) and 2 at 1.5 mm (1/16 in.)] shall be provided for 25 percent of the posts. Shims shall be similar to base plate in size and holes.

All splice bolts shall be M16 (5/8 in.) diameter unless otherwise noted.

Tubular Thrie Beam expansion joint shall be provided between any two posts which span a bridge expansion joint. Bolts located at expansion joints shall be provided with locknuts or double nuts and shall be tightened only to a point that will allow Tubular Thrie Beam movement.

The expansion joint width shall be 65 mm (2 1/2 in.) at 10 ºC (50 ºF) and shall be adjusted for other temperatures according to the requirements of Article 503.10(c).

509.06 Method of Measurement. Railings will be measured in meters (feet). The length paid for will be the overall length along the top longitudinal railing member through all posts and gaps.

509.07 Basis of Payment. Aluminum railing of the type specified will be paid for at the contract unit price per meter (foot) for ALUMINUM RAILING, which price shall include all materials, fabrication, transportation and erection.

Steel railing of the type specified will be paid for at the contract unit price per meter (foot) for STEEL RAILING, which price shall include all materials, fabrication, transportation, erection, cleaning, and painting.

Tubular Thrie Beam rail will be paid for at the contract unit price per meter (foot) for TUBULAR THRIE BEAM RETROFIT RAIL FOR BRIDGES, which price shall include all materials, fabrication, transportation, and erection.

SECTION 510. PIPE HANDRAIL

510.01 Description. This work shall consist of furnishing and erecting handrail where all posts and railing members are to be constructed exclusively with pipe.

510.02 Materials. Materials shall meet the following requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Steel Pipe	1006.18
(b) Malleable Iron Fittings	1006.16
(c) Paint	1008.01 - 1008.23

CONSTRUCTION REQUIREMENTS

510.03 Shop Drawings. When details are not fully shown on the plans, the Contractor shall submit duplicate copies of detailed shop drawings to the Engineer for approval before fabrication is begun. Design details shall meet the following requirements:

The railings shall be "Standard Weight" pipe and the posts "Extra Strong" pipe. Either welded or seamless pipe may be used. Rail panel lengths shall not exceed 2.1 m (7 ft) center-to-center of posts for 40 mm (1 1/2 in.) pipe and 2.4 m (8 ft) for larger diameter pipe. Provisions for expansion shall be made so that no railing will be continuous for more than 12 m (40 ft) without expansion joints. Generally, the railing shall not be fixed at both sides of more than three successive posts. Provision for expansion shall also be made in any panel across an expansion joint in the structure to which the handrail is attached.

At all points except expansion joints, connections of railings to posts shall be made either by the use of fittings or by continuous welding without fittings. Only one type of connection shall be used in the railings for any structure. All fittings shall be of the standard ball type.

When connections are made with fittings, end and corner posts shall be in one piece and pinned, riveted or welded to intermediate fittings through which the posts pass. Intermediate and expansion posts shall be in separate pieces, threaded or welded into fittings. Rails shall be continuous through fittings at intermediate posts where expansion is not provided, and shall be pinned, riveted or welded to the fittings. Rails shall be threaded or welded into fittings at end and corner posts and shall have slip connections into fittings at all points where expansion is provided.

When connections at posts, where expansion is not provided, are made by continuous welding, slip connections of railings into fittings or other approved means of providing for expansion shall be used at expansion posts.

The pipe handrail shall be fastened to the concrete or other support by means of standard flange plates with four anchor bolts each, or by other equally effective means approved by the Engineer. Anchor bolts for this purpose shall have a diameter of not less than 16 mm (5/8 in.).

510.04 Fabrication. Fabrication of pipe handrail shall conform to the applicable requirements of Article 505.04. All welded joints shall be continuous welds, and all weld areas shall be ground smooth. The use of couplings or unions will not be permitted. Threads shall be right-hand where possible. On grades over two percent, pipe handrails shall be fabricated so that the posts will be vertical when erected.

Shop inspection of pipe handrail shall conform to Article 505.05. Marking and shipping shall conform to the applicable requirements of Article 505.07.

510.05 Cleaning and Painting. Pipe handrail shall be painted with one shop coat of paint after being fabricated and two field coats of paint after erection. The

kind and color of paint shall be as stated on the plans or as determined by the Engineer. Cleaning and painting shall conform to the requirements of Section 506.

510.06 Erection. Whenever practicable, anchor bolts in concrete shall be placed before the concrete has set, otherwise, they shall be placed in holes drilled into the concrete, and all space not occupied by the bolt or anchoring devices shall be completely filled with mortar, or other suitable material approved by the Engineer. The erection of pipe handrail, including the handling and storing of materials, methods and equipment to be used shall conform to the applicable requirements of Article 505.08.

510.07 Method of Measurement. Pipe handrail will be measured for payment in meters (feet) of railing in place. Railing on a curve or grade will be measured along the curve or grade.

510.08 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for PIPE HANDRAIL, which price shall include all materials, fabrications, transportation, erection, cleaning and painting.

SECTION 511. SLOPE WALL

511.01 Description. The slope wall shall be constructed on an approved earth bed as specified.

511.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Portland Cement Concrete	1020
(b)	Fabric Reinforcement	1006.10

CONSTRUCTION REQUIREMENTS

511.03 General. The methods of construction shall comply with Sections 502 and 503. Preferably, the slope wall shall be constructed in alternate sections each approximately 2.7 m (9 ft) in width. The fabric reinforcement shall be supported 50 mm (2 in.) below the upper surface of the slope wall by concrete blocks. A clear distance of 50 mm (2 in.) shall be maintained between the fabric reinforcement and the outside face of any vertical or inclined toe or cutoff wall. The fabric reinforcement shall be continuous across all construction joints and shall extend into each section a minimum of 150 mm (6 in.) from any adjacent previously placed section. Adjacent sections of fabric reinforcement shall be lapped a minimum of 150 mm (6 in.) in all cases.

511.04 Curing and Protection. Equipment to be used for applying membrane curing, if used, shall meet the requirements of Article 1101.09(b).

511.05 Method of Measurement.

(a) Contract Quantities. The requirements of the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Slope wall will be measured for payment in place and the area computed in square meters (square yards). In computing the quantity for payment, the dimensions used will be those established by the Engineer to conform to the elevations of the natural ground line or stream bed. The area for measurement will include the upper, sloped surface of the wall. Anchor and cut-off walls will not be measured for payment, but shall be considered as included in the contract unit price bid for slope wall.

511.06 Basis of Payment. This work will be paid for at the contract unit price per square meter (square yard) for SLOPE WALL of the thickness specified, which price shall include payment for preparation of earth bed, excavation, backfilling,disposal of surplus material, and furnishing and placing all materials, including fabric reinforcement and anchor and cut-off walls.

SECTION 512. PILING

512.01 Description. This work shall consist of the furnishing, driving, building up and cutting off of timber, precast concrete, metal shell cast-in-place concrete with or without reinforcement bars and steel piles.

512.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Timber Piling	1007.08
(b) Preservative Treatment	1007.12
(c) Portland Cement Concrete	1020
(d) Reinforcement Bars and Fabric	1006.10
(e) Structural Steel	1006.04
(f) Paint Materials and Mixed Paints	1008.01 - 1008.23
(g) Prestressing Steel Strand	1006.10
(h) Metal Shell and Sheet Piling	1006.05

CONSTRUCTION REQUIREMENTS

512.03 Manufacture of Precast and Precast, Prestressed Concrete Piles. Precast and precast, prestressed piles shall be constructed according to the requirements of Section 504, except as specified.

(a) Precast Concrete Piles. Precast concrete piles may be driven when the tests show that the concrete has attained a compressive strength of not less than 31,000 kPa (4500 psi), or a flexural strength of not less than 5,200 kPa (750 psi), but not less than seven days from date of casting.

After removal of the side forms, the entire pile shall be supported for at least seven days from the time of casting, unless the concrete has attained the strength specified in a shorter period. In no case shall the piles be subjected to any handling stresses until the concrete has attained a flexural strength of at least 4,500 kPa (650 psi) or 24,000 kPa (3500 psi) compressive strength.

Each pile shall be cured according to Article 1020.13 until the concrete has attained the strength required at the time of driving, but for a period of not less than seven days from the date of casting, except as stated below. Steam curing also will be permitted, provided that the method and its details meet the approval of the Engineer. During cold weather construction and when steam curing is not used, the concrete shall be protected according to Article 1020.13(e). The curing and protection shall begin as soon as each group of piles has been cast. However, if the forms are to be removed on the day following the casting of the piles, the application of the protective covering may be deferred until the forms are removed unless the gain in strength will be unduly retarded thereby. Permission for removal of the protective covering after it has been applied, for the purpose of removing the forms, may be granted by the Engineer if this does not result in undue cooling of the concrete, but the covering shall be replaced after the shortest possible interval of time.

The maximum allowable deviation of the longitudinal axis from a straight line drawn from the center of the tip to the center of the butt shall not exceed 5 mm (1/4 in.) per 6.5 m (25 ft) of length of the pile.

(b) Precast, Prestressed Concrete Piles. Precast, prestressed concrete piles shall not be driven until the concrete has attained a compressive strength of not less than 35,000 kPa (5000 psi), but in no case less than three days from the date of casting.

The prestressing strand shall have a minimum breaking strength for 11 mm (7/16 in.) strand of 138 kN (31,000 lb) and a minimum load at one percent extension of 117 kN (26,350 lb) with an initial load of 14 kN (3,100 lb). The prestressing load applied to the strand shall be 96.5 kN (21,700 lb).

For 12.7 mm (1/2 in.) strand, the prestressing strand shall have a minimum breaking strength of 184 kN (41,300 lb) and a minimum load of 18 kN (4,130 lb). The prestressing load applied to the strand shall be 128 kN (28,900 lb).

Each reel of strand and all samples furnished to the Engineer for testing shall bear a tag identifying the strand as extra high-strength.

Each end of the piles shall have extra reinforcement as shown on the plans. All prestressing strands shall be ground flush with each end of the pile. The piles shall be constructed to a tolerance of 0 to +12 mm (+1/2 in.) of the cross sectional dimensions shown on the plans. The tolerance from a straight line along the longitudinal axis shall be the same as specified for precast concrete piles.

(c) Extensions or "Build-ups". Extensions, splices or "build-ups" on precast or precast, prestressed concrete piles, shall be avoided wherever possible; but when necessary, they shall be made as follows:

After driving is completed, the concrete at the end of the pile shall be cut away, leaving the reinforcement exposed for a length of 30 diameters of the bars for precast concrete piles and the prestressing strand exposed for a minimum length of 600 mm (24 in.) for precast prestressed concrete piles. The final cut shall be perpendicular to the axis of the pile. Reinforcement similar to that used in the pile shall be lapped 30 diameters and fastened to the projecting steel for precast concrete piles. Reinforcement as shown on the plans shall be lapped a minimum of 600 mm (24 in.) with the projecting prestressing strands for precast, prestressed concrete piles. In placing the form work for the extension, care shall be taken to avoid leakage along the pile. Prior to placing the concrete, the top of the pile shall be thoroughly wetted and covered with a thin coating of 1:2 cement mortar.

512.04 Metal Shell Cast-in-Place Concrete Piles. Metal shell cast-in-place concrete piles shall consist of concrete encased in a steel shell which is left in place.

(a) Metal Shells. All shells shall have the structural capacity to permit driving without distortion. Metal shells may be spliced provided that the minimum unspliced length of pile is 3 m (10 ft). A maximum of three shop or field splices will be allowed in any single pile for the authorized furnished length. Splicing shall be accomplished by a full butt weld. When the splice occurs in the footing or below, an approved commercial splicer may be used. Welder certification is not required for splicing metal shells. Material certification shall be furnished by the Contractor for each section of pile used in making the required splice.

(b) Inspection of Shells After Driving. The Contractor shall have available at all times a suitable light, of a type approved by the Engineer, for illuminating the interior of pile shells for their entire lengths after being driven. Any shell that is not watertight or that shows bends, kinks, or other deformations during the process of driving, that would impair the strength or efficiency of the completed pile, shall be either removed and replaced, or repaired by the Contractor, in a manner satisfactory to the Engineer. The Contractor will not be reimbursed for any such shells ordered removed or replaced by the Engineer. If the shells are not filled with concrete shortly after being driven, the tops of the shells shall be sealed temporarily to prevent the entrance of water or foreign substance.

(c) Reinforcement. Reinforcement shall be used for the concrete inside the shells when so provided by the plans. Such reinforcement shall be of the unit type, rigidly fastened together and lowered into the shell before the concrete is placed. Spurs or spacers shall be used to ensure the specified clearance for the bars.

(d) Filling Shells with Concrete. After the metal shells have been driven, cut off and approved, and any reinforcement required has been placed in position, the shell shall be filled with Class SI Concrete conforming to Section 1020. The entire depth of concrete in the pile shall be consolidated by internal

vibration. The depth of successive layers of concrete placed in the shells shall not exceed that which can be satisfactorily consolidated with the vibrating equipment used.

The shells shall be given a final inspection before they are filled with concrete and any water or foreign substance found in them shall be removed. Concrete shall not be placed in shells containing water. Whenever practicable, all the piles for any one bent, pier or abutment shall have been completely driven before any concrete is placed in the shells. If this is impracticable, driving of remaining piles shall be deferred until the concrete in all shells which have been filled has been in place for not less than 24 hours from the time placing is completed. The concrete shall be protected against low temperatures as required in Article 1020.13.

512.05 Steel Piles.

(a) Description. Steel piles shall consist of structural steel shapes of the sections indicated on the plans or otherwise authorized by the Engineer.

(b) Splices and Caps. Splices will be allowed when shown on the plans or approved by the Engineer. No more than one pre-planned field or shop splice will be allowed in any 12 m (40 ft) length of pile and no spliced length less than 8 m (25 ft) will be allowed. Splices shall develop the full structural capacity of the net cross section area of the pile. Splicing shall be accomplished by full penetration butt welding of the entire cross-section, by the Department's standard steel pile field splice, or by the use of an approved commercial splicer. Welder qualification and certification will be required for all splices according to Article 512.07. If steel caps are required by the plans, the piles shall be cut off evenly prior to placing the caps. Splices shall be made according to the details shown on the plans or as approved by the Engineer.

(c) Field Connections for Trestle Bents. Connections of caps and bracing members shall be made by machine bolts or by welding according to the details shown on the plans. When piles are not driven sufficiently exact to line up the faces of pile flanges with bracing members, fills or shims shall be furnished and placed by the Contractor to secure proper alignment of the bracing. The weight of such fills and shims will not be included in the weight of any structural steel for which the Contractor is to be paid.

(d) Painting. Before being driven or placed, all steel piles, caps, splices and bracing members in trestle bents shall be shop painted with inorganic zinc-rich primer. When specified, after the piles are driven and all bracing members, concrete caps and encasement are in place, all exposed steel shall be given one complete coat of field paint. All painting shall conform to Section 506. Foundation piles shall not be painted.

(e) Metal Shoes. When specified, steel H-piles shall be fitted with pile points of the design specified.

The pile points shall be cast in one piece steel conforming to ASTM A 27M (A 27) (Grade 65-35). They shall have sufficient flange and continuous web

vertical back-ups to assure proper alignment and fitting to the pile. They shall provide full bearing for the piles and shall be fastened to the piles using 8 mm (5/16 in.) continuous fillet weld along the flange contact areas. The soil or rock bearing surfaces of the points shall be sloped downward toward the web a minimum of 15º but not to exceed 30º to the horizontal under the flanges. The sloped surfaces of the points shall terminate in a manner to form a flat surface not exceeding one fourth of the flange width. These surfaces may have individual or continuous cutting teeth. The minimum mass (weight) of the pile points shall be according to the following schedule:

Pile Size	Min. Mass of Point- Kg. (lb)
HP 200 (HP 8)	7.0 (15)
HP 250 (HP 10)	10.0 (22)
HP 310 (HP 12)	13.0 (30)
HP 360 (HP 14)	20.0 (46)

512.06 Splicing Timber Piles. Where possible, full length piles shall be used. No splices may be made without the permission of the Engineer. When splices are permitted, they shall be of the butt joint type and the added piece shall conform closely in diameter to the main pile at the point of splice. The pile shall be sawed square and the butt joints shall bear evenly over the entire surface. The splices shall be made by the use of at least four steel plates or a metal pipe sleeve. The plates shall be at least 1.2 m (4 ft) long, 90 mm (3 1/2 in.) wide and 10 mm (3/8 in.) thick and each plate shall be bolted to the pile with not less than two M20 (3/4 in.) bolts both above and below the joint. Pipe sleeves shall be standard steel pipe, at least 900 mm (3 ft) long and shall be fastened with not less than three M16 (5/8 in.) lag screws, 125 mm (5 in.) long, both above and below the joint. All metal used for splicing creosoted piles shall be painted one coat of a metal protective paint approved by the Engineer. If exposed, the metal shall also be given two coats of field paint of an approved color.

Before the splice is assembled, if the joint is to be above low ground water line, all sawed surfaces and holes in creosoted and untreated piles shall be treated as provided in Article 1007.12(f).

512.07 Welding. All welding shall conform to the applicable requirements of Article 505.04(q). A welder may be qualified for fillet welds on steel piles by welding a test specimen according to the requirements of the Qualification Test for Fillet Welds Only (Option 1) of the AWS Specifications, except that the requirements for the macroetch specimen will be waived.

Welding will be permitted in all cases for splicing metal shells. Welder qualification requirements will be waived for splicing of metal shells. Welding shall be used for splicing steel piles and for attaching bracing or other steel members to steel piles, when specified.

512.08 Storage and Handling of Piles.

(a) General. The method of storing and handling all piles shall be such as to avoid damage to the piles.

(b) Creosoted Timber Piles. Creosoted timber piles shall be stored at the site of the work according to Article 1007.12(f) and handled as specified in Articles 507.05 and 1007.12(f).

(c) Precast and Precast, Prestressed Concrete Piles. Removal of forms, curing, storing, transporting, and handling precast and precast, prestressed concrete piles shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling or other injurious effects. In general, precast concrete piles shall be lifted by suitable devices attached to the pile at not less than two points for piles up to 14 m (45 ft) long, and not less than three points for piles over 14 m (45 ft) long. Precast prestressed concrete piles shall be lifted by suitable devices and supported during storage or transportation at not less than two points for piles up to 20 m (65 ft) long and not less than three points for piles over 20 m (65 ft) long. The locations of the points of support shall be as shown on the plans.

The piles may be lifted by a bridle attached to the pile or special embedded or attached lifting devices as approved by the Engineer. Unless special lifting devices are attached for lifting, the pickup points shall be plainly marked on all piles before removal from the casting bed and all lifting shall be done at these points. Deviation from the above method of handling will be permitted, subject to the approval of the Engineer. The method of handling precast concrete piles shall not induce stresses in the reinforcement in excess of 80,000 kPa (12,000 psi), allowing 100 percent of the calculated load for impact and shock. The method of handling precast prestressed concrete piles shall not induce tensile stresses in the concrete in excess of 1400 kPa (210 psi), allowing 100 percent of the calculated load for impact and shock.

(d) Steel Piles. The handling and storing of steel piles shall be done according to Article 505.08(c).

(e) Metal Shell Piles. Metal shell piles shall be stored off the ground with sufficient cribbing to prevent bending or distortion of the pile and to prevent dirt, water, or other foreign material from entering the metal shell.

512.09 Preparation for Driving. Foundation piles shall not be driven until after the excavation for the footings is completed. Any material forced up between the piles shall be removed to the correct elevation before concrete in the foundation is placed. Trestle piles and piles for abutments shall not be driven until any required channel excavation or excavation for backing and bracing is completed, at least at the location of the piles.

(a) Pointing Timber Piles. When necessary, timber piles shall be pointed for driving. Retreatment of the pointed area will not be required. When specified, the piles shall be shod with metal shoes of a design satisfactory to

the Engineer. The points of the piles shall be shaped to secure an even and uniform bearing on the shoes.

(b) Precast Concrete Piles. If the piles have been allowed to dry after curing, the entire pile shall be saturated at least six hours prior to driving.

512.10 Driving Piles. The equipment for driving piles shall be adequate for driving piles 3 m (10 ft) longer than the longest plan length shown on the plans. The equipment shall be capable of driving the entire length of pile without splicing. The use of a shorter length of equipment or the use of preplanned splices shall meet the approval of the Engineer. The pile hammer shall meet the approval of the Engineer. The equipment and methods for driving piles shall conform to the following requirements:

(a) Methods of Driving. Piles shall be driven with a gravity, steam, compressed air, or diesel hammer. Hydraulic hammers may be used with written approval of the Engineer. If a hydraulic is allowed, the Contractor shall furnish, at his/ her expense, wave equation analysis and a pile driving analyzer to aid in the determination of the adequacy of the hammer and the bearing capacity of the pile. The use of jets or other methods of pile driving shall meet the approval of the Engineer. The driving of each pile shall be continuous until the pile has attained the specified bearing capacity. The method of driving shall not result in damage to the pile.

(b) Caps, Helmets and Driving Heads. The heads of timber piles shall be protected by a cap during driving. The cap shall consist of a cushion made of wood. The design of the cap shall meet the approval of the Engineer.

The heads of steel piles shall be protected by a cast or structural steel helmet. The helmet shall be capable of holding the axis of the pile in line with the axis of the hammer and prevent damage to the pile during driving.

The heads of metal shell pile shall be protected by a combination driving head and pilot capable of distributing the hammer blow uniformly across the metal shell cross section and maintaining the alignment of the pile.

The heads of precast concrete and precast, prestressed concrete piles shall be protected by a cushioned driving head during driving to prevent damage to the pile.

(c) Driving Piles through Embankment. When called for on the plans, holes shall be precored for timber and for precast, precast prestressed, or cast-in-place concrete piles which are to be driven in an embankment area. After the embankment has been constructed, holes shall be drilled at proper locations through the embankment to the natural ground level and the piles shall be driven through these holes. If oversize holes are drilled, the void space outside of the pile shall be filled with dry loose sand.

Test piles may be driven before the embankment is placed, or they may be driven through the precored embankment as herein specified.

The cost of complying with these requirements will not be paid for separately but shall be considered as included in the unit prices bid for the pay items involved.

(d) Hammers for Timber Piles. Gravity hammers for driving timber piles preferably shall weigh not less than 13.3 kN (3000 lb), but lighter hammers may be used provided the minimum weight of the hammer is 9 kN (2000 lb) for required pile capacities of 142 kN (16 tons) or less, 11 kN (2500 lb) for required pile capacities of more than 142 kN (16 tons) but not more than 178 kN (20 tons), and 13.3 kN (3000 lb) for required pile capacities of more than 178 kN (20 tons) but not more than 222 kN (25 tons). The capacity of the piles as stated on the plans shall be used in determining the minimum weight of drop hammer permitted. The fall of the hammer shall be regulated so as to avoid injury to the piles, but shall in no case exceed 6 m (20 ft), and shall be between 4.3 m (14 ft) and 4.8 m (16 ft) at the time that the capacity is being determined as specified in Article 512.14(b). The Contractor shall establish the true weight of the hammer used on the work to the satisfaction of the Engineer. Steam, air or diesel hammers used for driving timber piles shall develop an energy of not less than 8100 J (6000 ft lb) per blow.

(e) Hammers for Precast and Precast, Prestressed Concrete Piles. Precast and precast, prestressed concrete piles shall be driven with a steam, air or diesel hammer. The hammer shall develop an energy per blow sufficient to achieve the required pile capacity with not more than ten blows per 25 mm (1 in.) at the final set.

(f) Hammers for Metal Shell Cast-in-Place Concrete Piles. Pile shells shall be driven with a steam, air or diesel hammer which shall develop an energy per blow sufficient to achieve the required pile capacity with not more than ten blows per 25 mm (1 in.) at the final set.

(g) Hammers for Steel Piles. Steel piles shall be driven with a steam, air or diesel hammer which shall develop an energy per blow of not less than that calculated in the following manner:

(1) Single acting steam or air hammers and open type diesel hammers
*** WH = 35P (WH = 0.1P)

(2) Double acting steam or air hammers and closed type diesel hammers
*** E = 35P (E = 0.1P)

(3) ***Where:

E= Energy in joules (foot pounds) per blow of striking parts of hammer.

H= Height of fall, millimeters (feet).

P= Safe allowable bearing value of piles in kiloNewtons (pounds) when driven vertically. For piles driven to design capacity, use capacity from plans in kiloNewtons (pounds). For piles specified to be driven to refusal, use P = 1.5 (.062 x sq mm pile cross section) [P = 1.5 (9000 x sq in. pile cross section)].

W = Force (Weight) of striking parts of hammer in kiloNewtons (pounds).

(h) Leads. Pile leads shall be used to maintain the alignment of the pile. Leads may be either fixed or swinging. Swinging leads shall be set or toed in the ground prior to the start of driving. The design of the leads shall accommodate the full length of pile, hammer and other required equipment and be capable of maintaining the alignment of the pile during driving within the tolerances specified.

(i) Followers. The driving of piles with followers shall be done only with the written permission of the Engineer. When followers are used, one pile in every group of ten shall be driven without a follower, by using a longer pile if necessary, and shall be used, in effect, as a test pile to determine the average bearing capacity of the group. This pile will be paid for as a permanent pile and not as a "test pile".

(j) Jets. Water and air jets shall be used when approved by the Engineer. The jets shall have the capacity to erode the material adjacent to the pile. Unless cast inside of concrete piles, the jets shall be free to move along the axis of the pile. The use of jets shall be discontinued before final set is reached. Unless otherwise approved by the Engineer, the piles shall be driven with the hammer for the final 600 mm (2 ft) of penetration after use of the jets has been discontinued.

512.11 Penetration of Piles. All piles shall be driven to a penetration such that the bearing value, as determined by the formulas in Article 512.14(b), is not less than that indicated on the plans.

Foundation piles shall be driven to a penetration of at least 3 m (10 ft) below bottom of footing, and other piles to a penetration of at least 3 m (10 ft) below undisturbed earth. Piles in stream beds or on the banks of streams, where marked erosion is expected, shall be driven to such penetration as the Engineer deems necessary as protection against scour.

If, after a test pile is driven through and below a hard stratum, the bearing value of the test pile drops below the capacity required by the plans, the Engineer may require the Contractor to drive the permanent piles through the hard stratum to a penetration at which the required capacity is again obtained.

Except as required above, and as otherwise required for test piles, the Contractor will not be required to drive any pile to a bearing value of more than 45 kN (5 tons) in excess of the bearing value required by the plans.

When production friction piles fail to achieve plan bearing capacities after driving the full finished lengths, these piles, when approved by the Engineer, can be left for a minimum of 24 hours to allow for soil setup before attempting to splice. After the waiting period has passed, the Contractor shall redrive one representative pile in each group of such piling to check the gain in bearing upon soil setup. The soil setup bearing shall be based on the number of redriving blows necessary to drive the pile

an additional 75 mm (3 in.). These piles may be accepted without splicing if they exhibit sufficient bearing capacity.

512.12 Tolerances in Driving. Foundation piles shall be driven with a variation from the vertical or from the required batter of not more than 10 mm/m (1/8 in./ft). Piles supporting caps or having bracing or backing attached to them shall be driven with sufficient accuracy in position and alignment so that, without injury to the piles by forcing them into correct position after driving, no pile is out of correct position at the base of the cap by more than 25 mm (1 in.) in any direction; or out of alignment by more than 50 mm (2 in.) at the bottom of the backing or bracing, or at the ground line if the latter is lower or if there is no backing or bracing. All piles seriously damaged in driving or driven out of position shall be pulled or cut off, as the Engineer may direct, and shall be replaced satisfactorily by the Contractor at his/her own expense.

512.13 Cutoffs. The tops of all piles shall be cut off perpendicular to the longitudinal axis of the pile at elevations established by the Engineer. Piles which support timber caps or grillages shall be sawed to conform to the plane of the bottom of the superimposed structure. In all cases, the amount of cutoff shall be sufficient to remove any portion of the pile top trimmed for driving or bruised during driving. All debris shall be removed from around the pile heads.

The heads of all creosoted timber piles, when not encased in concrete, shall be given three coats of a hot mixture of 60 percent creosote oil and 40 percent roofing pitch, or given three brush coats of hot creosote oil and covered with roofing pitch. Each pile head shall then be covered with a sheet of galvanized iron, not lighter than 0.701 mm (24 gage) and of sufficient area to project at least 100 mm (4 in.) outside the pile at any point, which shall be bent down over the pile to fit neatly and exclude water in the best possible manner. The edges shall be trimmed neatly and fastened to the pile face with large headed galvanized roofing nails.

The cutoff portions of all piles, including test piles, shall be retained and made available for use in splicing or building up piles if required until the pile driving is complete. Upon completion of the work, the cutoffs shall become the property of the Contractor and shall be disposed of by the Contractor at his/her expense.

512.14 Determination of Bearing Values. The bearing values will be determined by one of the following methods:

(a) By Loading Tests. When provided for on the plans or so ordered by the Engineer, the Contractor shall load one or more piles of a group to determine their safe bearing values. The pile load test shall be performed according to ASTM D 1143.

For piles driven by methods other than specified in Article 512.10(a), the Contractor will be required to determine the bearing value of the piles by loading tests as specified.

(b) By Formulas. If loading tests are not required, the following formulas will be used as a guide to determine the safe bearing values for piles driven in a vertical position:

For timber and steel piles and metal shells for cast-in-place piles:

Metric Formulas	
$P = \frac{WH}{6(S + 25.4)}$	for gravity hammers
$P = \frac{WH}{6(S + 2.54)}$	for single acting steam or air hammers, and open type diesel hammers;
$P = \frac{H(W + Ap)}{6(S + 2.54)}$ or $= \frac{E}{6(S + 2.54)}$	for double acting steam or air hammers, and closed type diesel hammers
For precast and precast prestressed concrete piles:	
$P = \frac{WH}{6\left(S + 2.54\frac{w}{W}\right)}$	for single acting steam or air hammers, and open type diesel hammers
$P = \frac{H(W + Ap)}{6\left(S + 2.54\frac{w}{W}\right)}$ or $= \frac{E}{6\left(S + 2.54\frac{w}{W}\right)}$	for double acting steam or air hammers, and closed type diesel hammers

English Formulas	
$P = \frac{2WH}{S + 1.0}$	for gravity hammers
$P = \frac{2WH}{S + 0.1}$	for single acting steam or air hammers, and open type diesel hammers;
$P = \frac{2H(W + Ap)}{S + 0.1}$ or $= \frac{2E}{S + 0.1}$	for double acting steam or air hammers, and closed type diesel hammers
For precast and precast prestressed concrete piles:	
$P = \frac{2WH}{S + 0.1\frac{w}{W}}$	for single acting steam or air hammers, and open type diesel hammers
$P = \frac{2H(W + Ap)}{S + 0.1\frac{w}{W}}$ or $= \frac{2E}{S + 0.1\frac{w}{W}}$	for double acting steam or air hammers, closed type diesel hammers

For piles driven to a batter, the safe bearing value of the pile along its axis will be taken as U times P, the value of U being determined as follows:

$U = \frac{0.25(4 - m)}{(1 + m^2)^{0.5}}$ for gravity hammers

$U = \frac{0.1(10 - m)}{(1 + m^2)^{0.5}}$ for steam or air hammers and diesel hammers

In the above formulas in this Article,

P = safe allowable bearing value of piles, in kiloNewton (pounds) when driven vertically;

W = weight of striking parts of hammer, in kiloNewton (pounds) w = weight of pile, in kiloNewton (pounds) H = height of fall, in millimeter (feet) A = area of piston, in square millimeters (square in.)

P = mean effective steam or air pressure in cylinder of hammer, in kiloNewton per square millimeter (pounds per square in.)

E = energy of the striking parts of the hammer, in joules (foot-pounds)per blow

S = average penetration, in millimeters (in.) per blow, for five to ten consecutive blows for gravity hammers, or ten to 20 consecutive blows for steam or air hammers and diesel hammers;

m = tangent of the angle of batter;

U = a coefficient, less than unity.

1 kg = 0.00981 kN

The Engineer will determine the value of "E", effective energy, of closed type diesel hammers, the effective energy being the energy developed by the compressed air and/or gas in the upper chamber plus the energy developed by the falling ram. All necessary gages and/or instruments shall meet the approval of the Engineer and they shall be furnished and properly installed by the Contractor who shall also furnish the Engineer with the specifications of the hammer that will be used to perform the work. No additional compensation will be allowed the Contractor for furnishing and installing the gages and/or instruments nor for furnishing the hammer specifications.

The preceding formulas for piles driven with a gravity hammer are applicable only when: the hammer has a free fall; the pile head is not broomed, crushed or splintered; there is no appreciable bounce of the hammer after striking the pile; the penetration is at a uniform or uniformly decreasing rate; and the average penetration of five consecutive blows is not less than 25 mm (1 in.) per blow under a free fall of the hammer.

When the penetration of a pile is almost wholly obtained by the use of jets, a hammer being used merely as an aid to force the pile into place and to secure the final 600 mm (2 ft), more or less, of penetration, the preceding formulas will not be used to determine the safe bearing value of the pile. For such jetted piles, the safe bearing value will be determined by actual loading tests as specified in paragraph (a) of this Article, unless, in the opinion of the Engineer, the pile will develop a safe frictional resistance.

512.15 Test Piles. When required by the plans, the Contractor shall furnish and drive test piles at locations determined by the Engineer. These piles shall be 3 m (10 ft) longer than the length of the permanent piles shown on the plans. When so instructed by the Engineer, the Contractor shall drive each test pile to refusal or to a capacity 50 percent greater than the capacity of any pile, the penetration of which is to be determined by the test pile. H-piles specified for refusal bearing shall be driven to refusal bearing P as defined in Article 512.10(g). Test piles shall be of the same

material and size as the permanent piles, except that, if creosoted piles are specified, untreated piles may be used by written permission of the Engineer, if not driven in a permanent location or within any footing area. If metal shoes are required on permanent piles, the test piles shall be provided with metal shoes of the same kind. Steel test piles driven in a permanent location shall be painted as specified for permanent steel piles. Test piles shall be driven with the same equipment as will be used for driving the permanent piles. Before driving test piles, the excavation shall be completed to an elevation not more than 600 mm (2 ft) above the proposed grade at the point where a test pile is to be driven except when piles are specified to be driven to point bearing. Test piles driven as permanent piles shall be cut off as permanent piles. Test piles not driven in a permanent location shall be cut off or pulled, as directed by the Engineer.

The bearing capacity of each test pile will be determined according to Article 512.14 and the lengths of the permanent piles to be furnished will be determined by the Engineer from these test piles.

512.16 Length of Piles. The Contractor shall furnish pile lengths according to a written itemized list provided by the Engineer. Should the Contractor elect to preorder piles prior to being furnished with the itemized list, it will be at his/her own risk. All costs associated with driving and splicing preordered piles that are shorter than the authorized furnished length shall be at the Contractor's expense. The authorized furnished length will be based on the Engineer's evaluation of the test pile results. If the plans do not require a test pile, the ordered length shall be as noted on the plans.

512.17 Method of Measurement. Piling will be measured for payment in the following manner:

(a) By Number. Test piles, pile test loadings and metal shoes will be measured by determining the number of each of these items.

(b) By Length. Furnishing and driving piles; furnishing, driving, and filling metal shells for cast-in-place concrete piles and cast-in-place concrete pile extensions will be measured in meters (feet). Measurement of lengths will be made to the nearest 0.1 m (0.1 ft).

(c) By Volume. Concrete encasement will be measured in cubic meters (cubic yards) according to Article 503.21.

512.18 Basis of Payment. Payment for piling will be made in the following manner:

(a) Furnishing Timber Piles. This work will be paid for at the contract unit price per meter (foot) for FURNISHING UNTREATED PILES and for FURNISHING CREOSOTED PILES. Payment will be made for the total number of meters (feet) of all piles which have been delivered to the site of the work, according to the itemized list furnished by the Engineer, and additional lengths ordered by the Engineer, and which have been accepted.

If a pile is furnished in a length different from the plan length but the length as furnished is within a length range for which a unit price is provided in the

contract, that pile will be paid for at the contract unit price for piles of that length range. If the length of a pile as furnished is not within a length range for which a price is provided in the contract, payment for that pile will be made at a unit price determined by multiplying the contract unit price for the length of that pile as shown on the plans by the percentages given in the following tables:

Length Range of Pile Shown in Contract meters (feet)	UNTREATED PILES		
	Percentage of Contract Unit Price		
	Length Furnished Up to 9 m (30 ft)	Length Furnished 9.1 m to 14 m (30.1 to 45 ft)	Length Furnished Over 14 m (45 ft)
Up to 9 (30)	100	115	125
9.1 (30.1) to 14 (45)	90	100	110
Over 14 (45)	85	95	100

Length Range of Pile Shown in Contract meters (feet)	CREOSOTED PILES		
	Percentage of Contract Unit Price		
	Length Furnished Up to 6.0 m (20 ft)	Length Furnished 6.1 m to 11.5 m (20.1 to 38 ft)	Length Furnished Over 11.5 m (38 ft)
Up to 6.0 (20)	100	115	125
6.1 (20.1) to 11.5 (38)	90	100	110
Over 11.5 (38)	85	95	100

The unit price per meter (foot) as provided in the contract or as above determined will be payment in full for furnishing the piles at the site of the work. No payment will be made for falsework piles or for splices and extensions which are made necessary by damage during driving.

(b) Furnishing Precast Concrete, Precast, Prestressed Concrete, Metal Shell and Steel Piles. This work will be paid for at the contract unit price per meter (foot) for FURNISHING PRECAST CONCRETE PILES, FURNISHING PRECAST PRESTRESSED CONCRETE PILES, FURNISHING METAL PILE SHELLS and FURNISHING STEEL PILES of the size designated. Payment will be made for the total number of meters (feet) of all piles which

have been delivered to or manufactured at the site of the work according to the itemized list furnished by the Engineer, and which have been accepted. This length will include additional lengths ordered by the Engineer and accepted, and "build-ups", except those for which payment for furnishing is provided in Article 512.18(f). The length of a "build-up" will include the length required to replace that portion of the main pile which is cut off in making the extension. No payment will be made for "build-ups" made necessary by damage to the piles during driving. The contract unit price per meter (foot) for furnishing steel piles shall include furnishing steel caps, if shown on the plans. If the plans provide for piles having an estimated length of 14 m (45 ft) of less and the piles as cast are to have a length of more than 14 m (45 ft), the additional weight of the longitudinal bars will be paid for according to Article 109.04.

(c) Driving Timber, Precast Concrete, Precast, Prestressed Concrete and Steel Piles and Driving and Filling Metal Shells for Cast-in-Place Concrete Piles.

This work will be paid for at the contract unit price per meter (foot) for DRIVING TIMBER PILES, DRIVING PRECAST CONCRETE PILES, DRIVING PRECAST, PRESTRESSED CONCRETE PILES, DRIVING STEEL PILES and DRIVING AND FILLING SHELLS, subject to the following terms and conditions.

Payment will be made for the total number of meters (feet) of all piles left in place. For timber, metal shell and steel piles, this length will include the length of all extensions below the cutoff. For precast and precast, prestressed concrete piles, this length will include the length of all "build-ups", but not the portion cut off for making the splice. The contract unit price will include payment for furnishing and placing concrete and reinforcing bars when required, in metal pile shells, and payment for erecting caps, if specified, for steel piles. No payment will be made for cutoffs, treatment of pile heads, defective shells or for driving falsework piles.

(d) Furnishing Concrete Piles. The piles furnished under this item shall be either Precast Concrete, Precast, Prestressed Concrete or Metal Shell Cast-in-Place Piles. The selection of the type of pile to be used shall be at the option of the Contractor from among those shown on the plans as alternates. This work will be paid for at the contract unit price per meter (foot) for FURNISHING CONCRETE PILES. The length paid for will be as specified in Article 512.18(b).

(e) Driving Concrete Piles. This work will be paid for at the contract unit price per meter (foot) for DRIVING CONCRETE PILES. Payment will be made for the total number of meters (feet) as specified in Article 512.18(c).

(f) Splices for Piles. No extra compensation will be allowed for splices for piles, except that, when splices are required because of the use of lengths in excess of those given in the itemized list furnished to the Contractor by the Engineer, such splices will be paid for according to Article 109.04. For timber piles, metal shells for cast-in-place concrete piles and steel piles, the extra work to be paid for will be the work involved in making the splice. For precast and precast, prestressed concrete piles, the extra work shall include

the removal of the portion cut off for making the splice and the furnishing of all materials and constructing the "build-up" above the splice.

(g) Concrete Encasement. The concrete encasement of steel piles and cast-in-place concrete piles will be paid for at the contract unit price per cubic meter (cubic yard) for CONCRETE ENCASEMENT, which price shall include payment for furnishing and placing the reinforcement required for the encasement and any excavation necessary to construct it.

(h) Cast-in-Place Pile Extensions. When metal shell cast-in-place concrete piles are to be extended with a reinforced concrete section above the top of the metal shell, that portion above the top of the metal shell will be paid for at the contract unit price per meter (foot) for CAST-IN-PLACE PILE

EXTENSIONS, which price will include payment for all reinforcement in the extensions and in the splices between the extensions and metal shell concrete piles. Concrete extending below the tops of the metal shells, and all reinforcement therein, will not be measured for payment but the cost will be included in the price for the extensions above the tops of the metal shells.

(i) Test Piles. Furnishing and driving test piles will be paid for at the contract unit price each for TEST PILES, of the type designated, which price will include all work specified in Article 512.15 or otherwise required for test piles to serve as permanent piles. Piles paid for as Test Piles will not be paid for under any other item.

(j) Loading Tests. Loading tests to determine the safe bearing value of a pile will be paid for at the contract unit price each for PILE TEST LOADING.

(k) Metal Shoes. The furnishing of metal shoes for piles, other than test piles, will be paid for at the contract unit price each for METAL SHOES which price shall include payment for attaching the shoes to the piles.

(l) When either of the following two conditions occur, the Engineer may authorize blasting and/or other work not otherwise provided for to obtain the specified penetration, and payment will be made according to Article 109.04.

(1) When it is specified that piles are to be driven to a predetermined bearing, and hard or firm material is encountered at locations where piles are being driven, and penetration cannot be obtained by ordinary driving and jetting as determined by the Engineer.

(2) When it is specified that piles are to be driven to a predetermined elevation regardless of bearing, and ledge rock or concrete which is indiscernible, or not shown on the plans, or mentioned in the Special Provisions is encountered.

SECTION 513. TEMPORARY BRIDGES

513.01 Description. This work shall consist of the construction of temporary bridges, their maintenance in a safe condition for traffic, and their removal and disposal.

513.02 Design. If complete plans are not furnished by the Department, the details of design, materials to be used, sizes, spacing and arrangement of members shall be determined by the Contractor and shall meet the approval of the Engineer. The highway loading, roadway width and overall length or waterway opening shall be as specified. The temporary bridge, including railings, shall be designed according to the AASHTO Standard Specifications for Highway Bridges. Temporary bridge plans furnished by the Contractor shall be sealed, attesting to their structural adequacy, by a Structural Engineer registered in the State of Illinois.

513.03 Materials. All materials shall meet the requirements of Section 1000 - Materials, except as modified herein. The lumber and timber used for the temporary bridge may be either new or used, and shall meet the approval of the Engineer as to quality and suitability for the use intended. Structural steel members not described by the plans shall also meet the approval of the Engineer as to quality and suitability. The outer bark shall be removed from piles in temporary bridges at points where bracing or backing is attached; otherwise, the requirements of Article 1007.08(c) concerning the removal of bark shall not apply. Hardware for temporary bridges need not be galvanized. Any paint required shall be furnished by the Contractor.

CONSTRUCTION REQUIREMENTS

513.04 Excavation and Fill. All excavation necessary for the construction of any temporary bridge, and all backfilling up to the original ground surface, shall be according to Section 502 and will not be measured for payment, except that rock excavation will be paid for as provided therein. All other excavation such as for channel changes or approach roadways to the temporary bridge shall conform to Section 200, and will be paid for separately, unless otherwise specified.

513.05 Piling and Timber. Except as modified herein, all work involving timber piles shall conform to the applicable requirements of Sections 507 and 512. The requirements concerning treatment of piling, treatment of holes and pile tops, and metal coverings for piles shall not apply.

Timber construction shall comply with the applicable requirements of Section 507, as determined by the Engineer. The requirements of that Section regarding the use of treated timber shall not apply. Timber shall be either rough or surfaced. Countersinking will not be required except in the vertical roadway face of wheel guards and under longitudinal floor planks.

513.06 Other Construction. No painting of structural steel will be required except as specified. Temporary bridge members of precast concrete shall be according to applicable requirements of Section 504.

513.07 Maintenance and Replacement. The Contractor shall maintain such temporary bridge in good condition during its period of service or until the completion of the work covered by his/her contract. All labor and materials required for such maintenance, including the repair of any damage caused by traffic, shall be furnished by the Contractor without additional compensation. After the construction of a temporary bridge has been completed, if it is damaged by flood, washed out or otherwise destroyed through no negligence of the Contractor, the cost of any necessary repairs or reconstruction will be borne by the Department.

513.08 Removal. After the new construction has been opened to traffic and the need for the temporary bridge has ceased to exist, it shall be removed by the Contractor, become the Contractor's property and be disposed of by the Contractor as provided in Article 501.02. No excavation or other material will be allowed to remain in the stream channel.

513.09 Basis of Payment. This work will be paid for at the contract unit price each for TEMPORARY BRIDGE COMPLETE, which price shall be payment in full for the temporary bridge, including the maintenance, removal and disposal of the structure.

SECTION 514. TEMPORARY BRIDGE RAIL

514.01 Description. This item shall consist of furnishing, constructing, painting, maintaining and removing a temporary steel bridge rail according to the details shown on the plans.

514.02 Materials. Materials, including the furnishing of all posts, steel tubing, bolts, rail splices and/or devices and other accessories for fastening the posts to the bridge deck, shall conform to the applicable portions of Section 509.

CONSTRUCTION REQUIREMENTS

514.03 General. Construction requirements shall conform to the applicable portions of Section 509. The bridge rail shall receive one coat of a steel prime paint.

After the removal of bolts and anchorage devices, all holes in deck to remain in place shall be filled with epoxy grout flush with the deck surface. Where anchor bolts are epoxy grouted in a deck to remain in place, after removal of the temporary bridge rail, the bolts shall be cut off flush with the deck surface.

The epoxy grout shall be a 100 percent solid, two-component, liquid epoxy-resin system that when mixed with compatible dry, sharp aggregates with angular - shaped particles will produce a high-strength grout that shall not shrink on curing. The epoxy shall be mixed and placed according to the manufacturer's recommendations.

514.04 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for TEMPORARY BRIDGE RAIL, measured in place, which price shall be payment in full for the temporary rail as shown on the plans, including its erection and removal for each stage of construction, painting, epoxy grout, cutting off bolts, maintenance and disposal of the bridge rail.

SECTION 515. NAME PLATES

515.01 Description. This work shall consist of the furnishing and installing of name plates.

515.02 Materials. Name plates shall be made of brass, bronze or other material as provided by the plans.

CONSTRUCTION REQUIREMENTS

515.03 General. The general features of design, the type, size and spacing of letters and figures, the items of information to be shown on all name plates for structures constructed under a given contract and the arrangement of these items, shall conform to drawings furnished by the Department. The surface of the name plate shall be polished. The details of manufacture and provisions for attaching each name plate shall conform to the plans and be suitable for the type of structure on which it is to be installed.

515.04 Installation. Each name plate shall be rigidly attached to the structure. On concrete structures, each brass or bronze name plate shall be embedded in the concrete and fastened by means of four brass or bronze bolts with countersunk heads, or four lugs cast integral with the plate. The bolts or lugs shall project at least 75 mm (3 in.) into the concrete beyond the back of the plate.

On steel truss spans, the plate shall be fastened on the steel member at the fabricating shop by brazing around the entire perimeter of the plate.

On steel rails, the plate shall be bolted on with four, M10 x 25 mm (3/8 in. x 1 in.) stainless steel or brass cap screws that are self tapping or drilled and tapped in the field.

515.05 Basis of Payment. Name plates will be paid for at the contract unit price each for NAME PLATES, which price shall include furnishing and mounting the name plate.

CULVERTS

SECTION 540. BOX CULVERTS

540.01 Description. This work shall consist of the construction of all cast-in-place and precast concrete box culverts.

540.02 Materials. Materials shall meet the requirements of Article 503.02 and Article 504.02.

540.03 Equipment. Equipment shall meet the requirements of Articles 503.03 and 504.03.

CONSTRUCTION REQUIREMENTS

540.04 General. Concrete box culverts shall be constructed according to the applicable portions of Section 503 for cast-in-place concrete box culverts and of Section 504 for precast concrete box culverts.

The Contractor shall have the option, when a cast-in-place concrete box culvert is specified, of constructing the box culvert using precast box culvert sections when the design cover is 150 mm (6 in.) minimum. The precast box culvert sections shall be designed for the same design cover and live load shown on the plans for cast-in-place box culvert and shall be of equal or larger size opening.

The Contractor shall be responsible for diverting the water flow from the construction area using a method meeting the approval of the Engineer. The cost of diverting the water flow shall be considered as included in the contract unit price bid for the box culvert being constructed and no additional compensation will be allowed.

540.05 Cast-In-Place Concrete Box Culverts. Concrete culvert footings shall be considered as consisting of all monolithic wingwall footings, all curtain walls below the flow line of the barrel, the base slab, and the sidewalls and wingwalls to a height of approximately 150 mm (6 in.) above the base slab.

Piling may be added or deleted from footings of culverts when the natural foundation conditions encountered make it necessary. The footings shall be redesigned, if necessary, to permit the addition of piles or to spread the footing for stable bearing.

The footings shall be placed as a monolith and allowed to set for a period of time sufficient to preclude the possibility of damage by subsequent work. In the construction of box culverts 2 m (6 ft) or less in vertical clearance, the side walls and top slab may be constructed as a monolith in the same placing operations. When this method of construction is used, any necessary construction joints shall be vertical and at right angles to the axis of the culvert. In box culverts of sufficient size to prohibit that part above the footing being completed in one continuous operation, horizontal construction joints will be permitted wherever necessary below the floor slab. A horizontal construction joint will be required below the top slab of any culvert having vertical clearance of more than 2 m (6 ft).

Cast-in-place concrete culvert slabs built to roadway grade shall be finished according to Article 503.17(c).

540.06 Precast Concrete Box Culverts. Precast concrete box culvert sections and end sections shall conform to the requirements of AASHTO M 273M (M 273) when the design cover is less than 600 mm (2 ft) but no less than 150 mm (6 in.) and AASHTO M 259M (M 259) when the design cover is 600 mm (2 ft) or greater but limited to maximum design covers shown in the tables.

Where cast-in-place headwalls and vertical cantilever wingwalls are used as shown in the contract plans, they shall be collared around the end of the precast section. Where cast-in-place horizontal cantilever wingwalls are used as shown in

the contract plans, they shall be poured monolithically with at least 2m (6 ft) of cast-in-place box section. The cast-in-place box section shall be collared around the end of the precast section. The cast-in-place collars shall be reinforced.

Shop plans for the precast concrete box culvert sections, precast or cast-in-place end sections and headwalls, and the cast-in-place collars shall be submitted according to the requirements of Article 504.04.

The excavation and backfilling for precast concrete box culverts shall be according to the requirements of Section 502 except a layer of porous granular material, at least 150 mm (6 in.) in thickness, shall be placed below the elevation of the bottom of the box. The porous granular material shall be gradation CA 7, CA 11, or CA 18 and shall be placed to extend at least 600 mm (2 ft) beyond each side of the box. The precast concrete box culvert shall be laid according to the applicable requirements of Article 542.04(d).

The joints between precast box sections shall be sealed and all voids filled with a mastic joint sealer. Mastic shall be according to Section 1055. In addition, the joints shall be externally sealed on all four sides using either 325 mm (13 in.) wide external sealing bands conforming to Article 1057.01 or 600 mm (24 in.) wide nonwoven geotechnical fabric meeting the requirements of Article 1080.01 except the minimum weight shall be 135 g/sq m (4 oz/sq yd). The seal or fabric shall be centered over the joint and secured to remain in place during the backfilling operation.

When multi-cells are used, a 75 mm (3 in.) nominal space shall be left between adjacent sections. After the precast cells are in place and backfill has been placed to midheight of the precast concrete box sections on each side, the space between the cells shall be filled with Class SI Concrete. The Class SI Concrete shall be according to Section 1020, except the maximum size coarse aggregate shall be 10 mm (3/8 in.).

540.07 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Concrete for cast-in-place box culverts will be measured for payment in cubic meters (cubic yards) as specified in Article 503.21.

Reinforcement bars for cast-in-place concrete box culverts will be measured for payment in kilograms (pounds) as specified in Article 508.07.

When precast concrete box culverts are specified on the plans, they will be measured for payment in meters (feet) except the length measured shall not exceed the length shown on the plans or authorized by the Engineer. The overall length shall be measured as shown on the plans along the centerline of each cell of the culvert. The end sections will be measured for payment in place as each. Cast-in-place collars, headwalls, cutoff walls, wingwalls, footings and Class SI Concrete cast-in-place between adjacent cells will not be measured for payment.

540.08 Basis of Payment. Cast-in-place concrete box culverts will be paid for at the contract unit price per cubic meter (cubic yard) for CONCRETE BOX CULVERTS. Reinforcement will be paid for according to Section 508.

Expansion bolts will be paid for at the contract unit price each for EXPANSION BOLTS of the size indicated.

When specified on the plans, precast concrete box culverts will be paid for at the contract unit price per meter (foot) for PRECAST CONCRETE BOX CULVERTS of the size specified, which price shall be payment in full for the work as specified and as shown on the plans, including all collars, porous granular bedding material, cast-in-place portions between cells, and excavation, except rock and excavation of unstable and unsuitable material removed below bedding grade.

End sections will be paid for at the contract unit price each for BOX CULVERT END SECTIONS of the culvert number specified, which price shall be payment in full for the work as specified and as shown on the plans, including cut-off walls, headwalls, wingwalls, footings and all cast-in-place portions of the barrel not specified above. If the Contractor, with the approval of the Engineer, elects use a different end section from that shown on the plans, no adjustment in the cost of the precast box culverts or end sections will be allowed.

When the plans specify cast-in-place concrete box culvert and the Contractor, at his/her option, constructs the alternate precast concrete box culvert, no adjustment in the cost for the specified cast-in-place culvert will be allowed. Compensation under the contract bid items for Concrete Box Culverts and Reinforcement Bars shall cover the cost for the precast concrete box culvert alternate complete, including all precast sections, cast-in-place portions, porous granular bedding material, and excavation, except excavation of rock and excavation of unstable and unsuitable material moved below bedding grade.

SECTION 541. CORRUGATED STRUCTURAL PLATE DRAINAGE STRUCTURES

541.01 Description. This work shall consist of furnishing and installing corrugated structural plate pipe culverts, corrugated structural plate pipe arches and corrugated structural plate arches, fabricated and erected in sections.

541.02 Materials. Materials shall meet the requirements of Article 1006.02. All steel channels, angles, bolts, washers, or other hardware shall be galvanized by the hot-dip process after fabrication. The Department reserves the right to specify either galvanized corrugated steel or aluminum alloy for any installation. When a particular material is specified, no other material will be permitted as an alternate.

When metric sizes are specified on the plans, the next larger available manufactured English size pipe may be used at no extra cost to the Department.

541.03 Plates. Plates shall consist of structural units of galvanized corrugated steel or aluminum alloy furnished in standard sizes to permit structure length increments of 600 mm (2 ft). The corrugations shall run at right angles to the longitudinal axis of the structure.

The plates at longitudinal and circumferential seams shall be staggered so that not more than 3 plates come together at one point.

The minimum cover over the top of corrugated structural plate drainage structures shall be as shown in Tables I and II for structural plate pipes and pipe arches. The minimum cover for arches shall be span/6 but not less than 300 mm (12 in.).

Plates for corrugated structural plate pipe culverts and for corrugated structural plate pipe arches shall be furnished in the thickness shown in Tables I and II for the respective size and cover over the pipe.

Plates for corrugated structural plate arches shall be furnished in the thickness shown on the plans.

TABLE IA. WALL THICKNESS FOR CORRUGATED STEEL STRUCTURAL PLATE PIPE CULVERTS For MS 18 LOADING															
Height of Cover to Nearest 0.1 Meter															
Dia. Of Pipe in mm	0.3*	0.5*	0.6* thru 4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.6	7.9
1500	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1650	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1800	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1950	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2100	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2250	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2400	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2550		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56
2700		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56
2850		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56
3000		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56
3150		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56
3300		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56
3450		2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3600		2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3750			2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3900			2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4050			2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4200			2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4350			2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32
4500			2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32

*Required minimum cover

TABLE IA. continued

Height of Cover to Nearest 0.1 Meter														
	8.2	8.5	8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9	12.2
1500	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1650	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1800	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56
1950	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2100	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2250	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2400	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2550	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2700	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2850	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32
3000	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32
3150	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32
3300	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3450	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3600	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3750	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3900	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78
4050	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78
4200	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78
4350	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78	4.78
4500	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78	4.78	4.78

TABLE IA. WALL THICKNESS FOR CORRUGATED STEEL STRUCTURAL PLATE PIPE CULVERTS
For H-20 LOADING
(ENGLISH)

Dia. of Pipe in In.	Height of Cover to Nearest Foot														
	1.0*	1.5*	2.0* thru 14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
60.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
66.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
72.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
78.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
84.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
90.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
96.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
102.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140
108.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140
114.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140
120.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140
126.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140
132.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140
138.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140
144.0		0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
150.0			0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
156.0			0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
162.0			0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
168.0			0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
174.0			0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170
180.0			0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170

*Required minimum cover

TABLE IA. English continued

Height of Cover to Nearest Foot														
	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
60.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
66.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
72.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140
78.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140
84.0	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
90.0	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
96.0	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
102.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
108.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
114.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170
120.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170
126.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170
132.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170
138.0	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
144.0	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
150.0	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
156.0	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188
162.0	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188
168.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188
174.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188	0.188
180.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188	0.188	0.188

TABLE IB. WALL THICKNESS FOR CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE PIPE CULVERTS
For MS 18 LOADING

Dia. of Pipe in mm	Height of Cover to Nearest 0.1 Meter																	
	0.3*	0.5*	0.6* thru 3.0	3.3	3.6	3.9	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.6
1500	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1650	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18
1800	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
1950	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
2100	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18
2250	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2400	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2550		2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2700		2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81
2850		2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81
3000		3.18	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81
3150		3.18	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81
3300		3.18	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81
3450		3.18	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81
3600		3.18	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	4.44
3750			2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	4.44	4.44
3900			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44
4050			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44
4200			3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44
4350			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	5.08
4500			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	5.08	5.08

* Required minimum cover

TABLE IB. continued

Height of Cover to Nearest 0.1 Meter															
	7.9	8.2	8.5	8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9	12.2
1500	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
1650	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81
1800	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81
1950	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81
2100	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
2250	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44
2400	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44
2550	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44
2700	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	5.08
2850	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08
3000	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.08
3150	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.08	5.72	5.72
3300	3.81	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	5.72
3450	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	5.72	6.35	6.35
3600	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35	6.35
3750	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35	6.35	
3900	4.44	4.44	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35				
4050	4.44	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35					
4200	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35						
4350	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35							
4500	5.08	5.72	5.72	5.72	6.35	6.35	6.35								

TABLE IB. WALL THICKNESS FOR CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE PIPE CULVERTS
For H-20 LOADING
(ENGLISH)

										Height of Cover to Nearest Foot								
Dia. of Pipe in In.	1.0*	1.5*	2.0* thru 10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0
60.0	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
66.0	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125
72.0	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
78.0	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
84.0	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125
90.0	0.1000	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
96.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
102.0		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
108.0		0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150
114.0		0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150
120.0		0.125	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150
126.0		0.125	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150
132.0		0.125	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150
138.0		0.125	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150
144.0		0.125	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.175
150.0			0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.175	0.175
156.0			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175
162.0			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175
168.0			0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175
174.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.200
180.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.200	0.200

*Required minimum cover

TABLE IB. continued
(ENGLISH)

	Height of Cover to Nearest Foot														
	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
60.0	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
66.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150
72.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150
78.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150
84.0	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
90.0	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175
96.0	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175
102.0	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175
108.0	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.200
114.0	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200
120.0	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.200
126.0	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.200	0.225	0.225
132.0	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.225
138.0	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.225	0.250	0.250
144.0	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250	0.250
150.0	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250	0.250	
156.0	0.175	0.175	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250				
162.0	0.175	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250					
168.0	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250						
174.0	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250							
180.0	0.200	0.225	0.225	0.225	0.250	0.250	0.250								

TABLE IIA SIZES. LAYOUT DETAILS AND WALL THICKNESSES FOR CORRUGATED STEEL STRUCTURAL PLATE PIPE ARCHES For MS 18 LOADING

Span mm	Rise Mm	Area m2	"B" mm	Height of Cover to Nearest 0.1 meter															
				0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
1854	1397	2.0	533	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
1930	1448	2.2	521	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2057	1499	2.4	559	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2134	1549	2.6	544	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2210	1600	2.9	528	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2337	1651	3.1	569	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2413	1702	3.3	551	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2489	1753	3.5	531		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2616	1803	3.7	577		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2692	1854	4.0	554		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2845	1905	4.3	605		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2896	1956	4.6	582		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2972	2007	4.8	556		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3124	2057	5.1	607		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3251	2108	5.4	663		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3327	2159	5.7	638		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3480	2210	5.9	696		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77

* Required minimum cover

"B" Is the vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch

TABLE IIA continued

Span mm	Rise mm	Area m2	"B" mm	Height of Cover to Nearest 0.1 Meter															
				0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
3531	2261	6.2	668		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3607	2311	6.6	640		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3759	2362	6.9	699			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3810	2413	7.2	671			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
3861	2464	7.5	671			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
3912	2540	7.9	610			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
4089	2565	8.3	668			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**	**2.77**
4242	2616	8.6	734			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**	**2.77**
4039	2845	9.0	978			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4115	2896	9.5	958			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4267	2946	9.8	1006			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4318	2997	10.1	986			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4394	3048	10.6	963			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4547	3099	11.0	1011			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4674	3150	11.4	1062			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4750	3200	11.8	1039			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4826	3251	12.3	1016			3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
4953	3302	12.7	1069				3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
5029	3353	13.2	1044				3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51

Bold type Indicates areas where soil bearing pressure approximately 290 kPa is required

* Required minimum cover

"B" is the vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIA SIZES. LAYOUT DETAILS AND WALL THICKNESSES FOR CORRUGATED STEEL STRUCTURAL PLATE PIPE ARCHES For H-20 LOADING
(ENGLISH)

Span In.	Rise In.	Area Sq Ft	"B"	Height of Cover to Nearest Foot																
				1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
73	55	22	21.0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
76	57	24	20.5	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
81	59	26	22.0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
84	61	28	21.4	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
87	63	31	20.8	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
92	65	33	22.4	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
95	67	35	21.7	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
98	69	38	20.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
103	71	40	22.7		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
106	73	43	21.8		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
112	75	46	23.8		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
114	77	49	22.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
117	79	52	21.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
123	81	55	23.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
128	83	58	26.1		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
131	85	61	25.1		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
137	87	64	27.4		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109

Required minimum cover

"B" Is the horizontal distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIA continued
(ENGLISH)

Span In.	Rise In.	Area Sq Ft	"B" In.	Height of Cover to Nearest Foot															
				1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
139	89	67	26.3		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
142	91	71	25.2		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
148	93	74	27.5			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
150	95	78	26.4			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
152	97	81	26.4			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
154	100	85	24.0			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
161	101	89	26.3			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**	**0.109**
167	103	93	28.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**	**0.109**
159	112	97	38.5			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
162	114	102	37.7			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
168	116	105	39.6			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
170	118	109	38.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
173	120	114	37.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
179	122	118	39.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
184	124	123	41.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
187	126	127	40.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
190	128	132	40.0			0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
195	130	137	42.1				0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
198	132	142	41.1				0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138

Bold type Indicates areas where soil bearing pressure approx. 3.0 tons per sq ft is required.

* Required minimum cover

"B" is the vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIB SIZES, LAYOUT DETAILS and WALL THICKNESSES for CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE PIPE ARCHES FOR MS 18 LOADING

Span	Rise	Area	"B"	Height of Cover to Nearest 0.1 Meter																
mm	Mm	m^2	mm	0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
1803	1651	2.3	808	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1880	1727	2.5	815	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1981	1753	2.8	813	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2083	1803	3.0	826	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2210	1829	3.3	841	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2311	1880	3.4	861	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2413	1930	3.7	856	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2489	1956	3.9	820		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2616	2007	4.2	841		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2692	2057	4.5	828		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2819	2083	4.7	853		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18
2946	2134	5.0	879		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18
3073	2159	5.3	912		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18
3175	2210	5.6	897		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3251	2261	5.9	881		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3353	2311	6.1	864		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3505	2337	6.4	953		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3556	2388	6.8	879		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3683	2413	7.1	914			2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3785	2464	7.4	894			2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18
3912	2515	7.7	935			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
3988	2540	8.1	912			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4140	2591	8.5	953			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4267	2616	8.7	1001			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4242	2870	9.5	1001			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4343	2921	9.8	1067			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4470	2946	10.2	1118			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4547	2997	10.6	1097			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4674	3048	11.1	1151			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4750	3099	11.4	1128			4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
4902	3150	11.9	1184				4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
4978	3200	12.3	1161				4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
5105	3251	12.7	1217				5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
5182	3302	13.2	1191				5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08

* Required minimum cover

"B" Is the vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIB SIZES, LAYOUT DETAILS and WALL THICKNESSES for CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE PIPE ARCHES FOR H-20 LOADING
(ENGLISH)

Span	Rise	Area	Height of Cover to Nearest Foot																	
In.	In.	Sq Ft	"B"	1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
71	65	25	31.8"	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
74	68	27	32.1"	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
78	69	30	32.0"	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
82	71	32	32.5"	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
87	72	35	33.1"	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
91	74	37	33.9"	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
95	76	40	33.7"	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
98	77	42	32.3"		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
103	79	45	33.1"		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
106	81	48	32.6"		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
111	82	51	33.6"		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125
116	84	54	34.6"		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125
121	85	57	35.9"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125
125	87	60	35.3"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
128	89	63	34.7"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
132	91	66	34.0"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
138	92	69	37.5"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
140	94	73	34.6"		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
145	95	76	36.0"			0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
149	97	80	35.2"			0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125
154	99	83	36.8"			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
157	100	87	35.9"			0.125	0.1 25	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
163	102	91	37.5"			0.125	0.1 25	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
168	103	94	39.4"			0.125	0.1 25	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
167	113	102	39.4"			0.125	0.1 25	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
171	115	106	42.0"			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
176	116	110	44.0"			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
179	118	114	43.2"			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
184	120	119	45.3"			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
187	122	123	44.4"			0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
193	124	128	46.6"				0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
196	126	132	45.7"				0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
201	128	137	47.9"				0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
204	130	142	46.9"				0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

* Required minimum cover

"B" Is the vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

541.04 Shipping and Storing. The loading, transporting, unloading, and storing of material shall be conducted so the steel and aluminum will be kept free from damage. Special care shall be taken to prevent disturbing the curvature in the plates. They shall be blocked to prevent injury during shipment and storage.

CONSTRUCTION REQUIREMENTS

541.05 Bearing Surfaces for Corrugated Structural Plate Arches. Each side of each arch shall rest in a groove formed into the masonry or shall rest on a galvanized structural steel angle or channel securely anchored to or embedded in the substructure. Where the span of the arch is greater than 4.5 m (15 ft) or where the skew angle is more than 20 degrees, a steel bearing surface, having a width at least equal to the depth of corrugation, shall be provided for all arches.

Steel bearings may be either galvanized structural steel channels or angles with horizontal leg securely anchored to the substructure. Channels shall be not less than 5 mm (3/16 in.) in thickness. Angles shall be not less than 75 mm (3 in.) by 75 mm (3 in.) by 6 mm (1/4 in.).

Where the steel bearing is not embedded in a groove in the substructure, one vertical leg shall be punched to allow bolting to the bottom row of plates.

541.06 Erection and Backfill. The erection and backfill for corrugated structural plate drainage structures shall conform to the following requirements:

(a) Corrugated Structural Plate Pipe Culverts and Corrugated Structural Plate Pipe Arches. When a plate pipe structure is to be erected in a trench, the width of the trench shall be sufficient to permit thorough tamping of the earth backfill against every plate. The pipe shall be bedded on an earth foundation of uniform density shaped to fit the lower plate at the proper grade. Any soil below the foundation grade which has been disturbed by the Contractor's operations shall be removed. If the foundation excavation has been made deeper than necessary, the foundation shall be brought to proper grade by the addition of well-compacted fine aggregate.

Where a firm foundation is not encountered at the grade established, due to soft, spongy, or other unsuitable soil, all such unsuitable soil under the plate pipe structure and for a width of at least one diameter on each side of the structure, shall be removed and replaced with well compacted fine aggregate.

Where rock, in either ledge or boulder formation is encountered, it shall be removed and replaced with a cushion of well-compacted fine aggregate to a depth below the structure of not less than 40 mm/m (1/2 in./ft) of height of fill over the top of the structure, with a minimum allowable thickness of 200 mm (8 in.).

All excavated material not needed on the work shall be disposed of by the Contractor as specified in Article 502.11.

When a corrugated structural plate pipe culvert or corrugated structural plate pipe arch has been completely erected in place, moist fine aggregate meeting the gradations specified in Article 1003.04 shall be placed alongside the structure in layers not to exceed 200 mm (8 in.) in depth, loose measurement, and compacted for the full width of the trench, or so that on each side of the structure there shall be a berm of compacted or undisturbed soil at least as wide as the greatest external dimension of the structure. The fine aggregate shall be placed longitudinally along the structure, except at the outer 1 m (3 ft) at each end of the structure, impervious material shall be used. The elevation of the backfill material on each side of the structure shall be the same. Special care shall be taken to compact the fine aggregate and impervious material under the haunches of the pipe. The backfill material, fine aggregate and impervious material shall be compacted to the satisfaction of the Engineer by mechanical means. This method of placement shall be continued until the top of the structure is covered with at least 300 mm (12 in.) of backfill material.

(b) Corrugated Structural Plate Arches. Excavation for corrugated structural plate arches shall conform to the applicable provisions of Section 502.

When backfilling a structure before headwalls are placed, the first material shall be placed midway between the ends of the arch forming as narrow a ramp as possible until the top of the arch is reached. The ramp shall be built evenly from both sides, and the backfilling material shall be thoroughly compacted as it is placed. After the ramps have been built to the top of the arch, the remainder of the backfill shall be deposited from the top of the arch, both ways from the center to the ends, and as evenly as possible on both sides of the arch.

If the headwalls are built before the structure is backfilled, the filling material shall first be placed adjacent to one headwall until the top of the arch is reached, after which the fill shall be dumped from the top of the arch toward the other headwall, with care being taken to deposit the material evenly on both sides of the arch.

In multiple installations, the procedure above specified shall be followed, but extreme care shall be used to bring the backfill up evenly on each side of each arch so that unequal pressure will be avoided.

In all cases, the filling material shall be thoroughly but not excessively tamped. Puddling the backfill will not be permitted.

After the structure has been covered with 300 mm (12 in.) of backfill, additional embankment shall be constructed as specified under the subheading "Additional Embankment" in Article 542.04. The height of the additional embankment shall be that specified. No additional compensation will be allowed the Contractor for constructing or removing all or part of the additional embankment.

541.07 Workmanship. In addition to compliance with the required details of construction, the completed structural plate structure shall show careful, finished workmanship in all particulars. Plates on which the zinc coating has been damaged or broken, or which show defective workmanship, will be rejected. The following defects are specified as constituting poor workmanship and the presence of any or all

of them in any individual plate or in any shipment shall be cause for rejection of the plate or shipment:

(1) Uneven laps.
(2) Elliptical shaping (unless specified).
(3) Variation from a straight centerline.
(4) Ragged edges.
(5) Loose, or unevenly lined or spaced bolts.
(6) Bruised, scaled or broken zinc coating.
(7) Dents or bends in the metal.

541.08 Method of Measurement. Corrugated structural plate drainage structures of the types and sizes specified, or of a particular material when specified, will be measured for payment in place in meters (feet). Measurement will be from end to end along the flow line of pipes and along the bearing leg of structural plate arches.

541.09 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for CORRUGATED STRUCTURAL PLATE PIPE CULVERTS of the diameter specified, CORRUGATED STRUCTURAL PLATE PIPE ARCHES of the area specified and CORRUGATED STRUCTURAL PLATE ARCHES of the area specified, which prices shall include all plates, hardware, steel bearings and other materials required, except concrete foundations, and the cost of all structure excavation required except for excavation for steel plate arches and excavation of rock and unstable or unsuitable material.

Excavation for corrugated structural plate arches and rock excavation will be measured and paid for as provided in Section 502.

The removal of unstable or unsuitable material or rock below foundation grade and the replacement thereof with the specified material, including additional excavation required to widen the trench, if required, will be paid for according to Article 109.04, unless the contract contains unit prices for the work included.

SECTION 542. PIPE CULVERTS

542.01 Description. This work shall consist of furnishing and installing pipe culverts of the required size. The Type of fill heights shall be as follows:

Fill Heights Over Top of Pipe	Type
1 m (3 ft)or less	Type 1
Greater than 1 m (3 ft), not exceeding 3 m (10 ft)	Type 2
Greater than 3 m (10 ft), not exceeding 4.5 m (15 ft)	Type 3
Greater than 4.5 m (15 ft), not exceeding 6 m (20 ft)	Type 4
Greater than 6 m (20 ft), not exceeding 7.5 m (25 ft)	Type 5
Greater than 7.5 m (25 ft), not exceeding 9 m (30 ft)	Type 6
Greater than 9 m (30 ft), not exceeding 10.5 m (35 ft)	Type 7
Greater than 10.5 m (35 ft)	Special

542.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Corrugated Steel Culvert Pipe	1006.01
(b)	Corrugated Steel Pipe Arch	1006.01
(c)	Precoated Galvanized Corrugated Steel Culvert Pipe	1006.01
(d)	Precoated Galvanized Corrugated Steel Pipe Arch	1006.01
(e)	Aluminized Steel Type 2 Corrugated Culvert Pipe	1006.01
(f)	Aluminized Steel Type 2 Corrugated Pipe Arch	1006.01
(g)	Bituminous Coated Corrugated Steel Culvert Pipe	1006.01
(h)	Bituminous Coated Corrugated Steel Pipe Arch	1006.01
(i)	Zinc and Aramid Fiber Composite Coated Corrugated Steel Pipe	1006.01
(j)	Corrugated Aluminum Alloy Pipe	1006.03
(k)	Corrugated Aluminum Alloy Culvert Pipe Arch	1006.03
(l)	Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe	1040.07
(m)	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe	1040.03
(n)	Concrete Sewer, Storm Drain, and Culvert Pipe	1040.04
(o)	Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe	1040.05
(p)	Polyvinyl Chloride (PVC) Pipe	1040.10
(q)	Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior	1040.15
(r)	Polyvinyl Chloride (PVC) Profile Wall Pipe-794	1040.24
(s)	Polyethylene (PE) Pipe with a Smooth Interior	1040.16
(t)	Polyethylene (PE) Profile Wall Pipe	1040.23
(u)	Polyvinyl Chloride (PVC) Profile Wall Pipe-304	1040.25
(v)	Corrugated Polyethylene (PE) Pipe with a Smooth Interior	1040.22
(w)	Extra Strength Clay Pipe	1040.02
(x)	Clay Sewer Pipe Pipe	1040.02
(y)	Preformed Flexible Gaskets for Sewer and Culvert Pipe	1056
(z)	Mastic Joint Sealer for Pipe	1055
(aa)	External Sealing Bank	1057

542.03 Material Permitted. The following materials will be permitted as alternates for pipe culverts of the class and type specified. Where a particular material is specified, no other kind of material will be permitted as an alternate.

Class	Material
A	Reinforced Concrete (Article 1040.03) Reinforced Concrete Arch Culvert (Article 1040.07) Reinforced Concrete Elliptical Culvert, Storm Drain, & Sewer Pipe (Article 1040.05)
C	Reinforced Concrete (Article 1040.03) Reinforced Concrete Arch Culvert (Article 1040.07) Reinforced Concrete Elliptical Culvert, Storm Drain & Sewer Pipe (Article 1040.05) Polyvinyl Chloride (PVC) Pipe (Article 1040.10) Corrugated Polyvinyl Chloride (PVC) Pipe with a

Smooth Interior (Article 1040.15)
Polyvinyl Chloride (PVC) Profile Wall Pipe-794 (Article 1040.24)
Polyvinyl Chloride (PVC) Profile Wall Pipe-304 (Article 1040.25)
Polyethylene (PE) Pipe with a Smooth Interior (Article 1040.16)
Polyethylene (PE) Profile Wall Pipe (Article 1040.23)
Aluminized Steel Type 2 Corrugated Culvert Pipe (Article 1006.01(i))
Aluminized Steel Type 2 Corrugated Pipe Arch (Article 1006.01(i))
Precoated Galvanized Corrugated Steel Culvert Pipe (Article 1006.01(c))
Precoated Galvanized Corrugated Steel Pipe Arch (Article 1006.01(c))
Corrugated Aluminum Alloy Pipe (Article 1006.03)
Corrugated Aluminum Alloy Pipe Arch (Article 1006.03)

D
Reinforced Concrete (Article 1040.03)
Reinforced Concrete Arch Culvert (Article 1040.07)
Reinforced Concrete Elliptical Culvert, Storm Drain & Sewer Pipe (Article 1040.05)
Polyvinyl Chloride (PVC) Pipe (Article 1040.10)
Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior (Article 1040.15)
Polyvinyl Chloride (PVC) Profile Wall Pipe-794 (Article 1040.24)
Polyvinyl Chloride (PVC) Profile Wall Pipe-304 (Article 1040.25)
Polyethylene (PE) Pipe with a Smooth Interior (Article 1040.16)
Polyethylene (PE) Profile Wall Pipe (Article 1040.23)
Aluminized Steel Type 2 Corrugated Culvert Pipe (Article 1006.01(i))
Aluminized Steel Type 2 Corrugated Pipe Arch (Article 1006.01(i))
Precoated Galvanized Corrugated Steel Culvert Pipe (Article 1006.01(c))
Precoated Galvanized Corrugated Steel Pipe Arch (Article 1006.01(c))
Corrugated Aluminum Alloy Pipe (Article 1006.03)
Corrugated Aluminum Alloy Pipe Arch (Article 1006.03)
Corrugated Polyethylene (PE) Pipe with a Smooth Interior (Article 1040.23)
Corrugated Steel Culvert Pipe (Article 1006.01(a))
Corrugated Steel Pipe Arch (Article 1006.01(a))
Bituminous Coated Corrugated Steel Culvert Pipe (Article 1006.01(b))
Bituminous Coated Corrugated Steel Pipe Arch (Article 1006.01(b))
Zinc and Aramid Fiber Composite Coated Corrugated Steel Pipe (Article 1006.01(h))

When metric sizes are specified on the plans, the next larger available manufactured English pipe may be substituted at no extra cost to the Department.

Where no end treatment is specified, a standard corrugated PE coupling shall be provided at each exposed end with the end of the coupling flush with the end treatment on all PE pipe culverts.

The Contractor may, without additional compensation, substitute a stronger pipe of the same kind of material specified.

For pipe culverts, only a circular pipe will be permitted when pipe culvert is specified to a diameter and only reinforced concrete elliptical, reinforced concrete arch, aluminum alloy arch, or steel arch will be permitted when pipe culvert is specified as round size equivalent.

Steel or aluminum alloy arch and concrete elliptical or arch pipes will be designated pipe culverts, special for fill heights exceeding 4.5 m (15 ft).

Extra Strength Clay Pipe and Concrete Sewer Storm Drain, and Culvert Pipe, Class 3, will be permitted for Pipe Culverts Types 2 and 3 only, for all pipe classes.

The kind of material and thickness or thickness class required for the various types of pipe culverts shall be according to Table IA, IB, IC, 11A, IIB, and IIIA-C.

TABLE IA: CLASSES OF REINFORCED CONCRETE PIPE FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Nominal Diameter mm	Fill Height: 1 m and less 0.3 m min. fill ht. over pipe	Fill Height: Greater than 1 m Not exceeding 3.0 m	Fill Height: Greater than 3.0 m Not exceeding 4.5 m	Fill Height: Greater than 5 Not exceeding 6 m	Fill Height: Greater than m Not exceeding 7.5 m	Fill Height: Greater than 6.0 m Not exceeding 9 m	Fill Height: Greater than 7.5 m Not exceeding 10.5 m
300	IV	II	III	IV	V	V	V
375	IV	II	III	IV	V	V	V
450	IV	II	III	IV	IV	V	V
525	IV	II	III	IV	IV	V	V
600	IV	II	III	IV	IV	V	V
750	IV	II	III	IV	IV	V	V
825	IV	II	III	IV	IV	V	V
900	III	II	III	IV	IV	V	V
1050	III	II	III	IV	IV	V	V
1200	II	II	III	IV	IV	V	V
1350	II	II	III	IV	IV	V	V
1500	I	I	I	III	IV	V	V
1650	I	I	I	III	IV	V	V
1800	I	I	III	IV	V	V	V
1950	I	I	III	IV	*V	*V	*V
2100	I	I	III	IV	*V	*V	*V
2250	I	I	III	*IV	*V	*V	*V
2400	I	I	III	*IV	*V	*V	*V
2550	I	I	III	*IV	*V	*V	*V
2700	I	I	III	*IV	*V	*V	*V

* Special Design Required

(ENGLISH)
TABLE IA: CLASSES OF REINFORCED CONCRETE PIPE FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Nominal Diameter in.	Type 1 Fill Height: 3' and less 1'-0" min. fill ht. over pipe	Type 2 Fill Height: Greater than 3' Not exceeding 10'	Type 3 Fill Height: Greater than 10' Not exceeding 15'	Type 4 Fill Height: Greater than 15' Not exceeding 20'	Type 5 Fill Height: Greater than 20' Not exceeding 25'	Type 6 Fill Height: Greater than 25' Not exceeding 30'	Type 7 Fill Height: Greater than 30' Not exceeding 35'
12	IV	II	III	IV	V	V	V
15	IV	II	III	IV	V	V	V
18	IV	II	III	IV	IV	V	V
21	IV	II	III	IV	IV	V	V
24	IV	II	III	IV	IV	V	V
30	IV	II	III	IV	IV	V	V
36	III	II	III	IV	IV	V	V
42	III	II	III	IV	IV	V	V
48	II	II	III	IV	IV	V	V
54	II	II	III	IV	IV	V	V
60	I	I	I	III	IV	V	V
66	I	I	I	III	IV	V	V
72	I	I	III	IV	V	V	V
78	I	I	III	IV	*V	*V	*V
84	I	I	III	IV	*V	*V	*V
90	I	I	III	*IV	*V	*V	*V
96	I	I	III	*IV	*V	*V	*V
102	I	I	III	*IV	*V	*V	*V
108	I	I	III	*IV	*V	*V	*V

* Special Design Required

TABLE IB: THICKNESS OF CORRUGATED STEEL PIPE FOR THE RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 68 mm x 13 mm AND 75 mm x 25 mm CORRUGATIONS

	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6		Type 7	
Nominal Diameter mm	Fill Height: 1 m and less 0.3 m min. fill over pipe		Fill Height: Greater than 1 m Not exceeding 3 m		Fill Height: Greater than 3 m Not exceeding 4.5 m		Fill Height: Greater than 4.5 m Not exceeding 6.0 m		Fill Height: Greater than 6.0 m Not exceeding 7.5 m		Fill Height: Greater than 7.5 m Not exceeding 9.0 m		Fill Height: Greater than 9.0 m Not exceeding 10.5 m	
	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm
**250	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
300	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
400	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
450	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
500	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
600	2.01		2.01		2.01		2.01		2.01		2.01		2.77	
700	2.01		2.01		2.01		2.01		2.01		2.77		3.51	
800	2.01		2.01		2.01		2.01		2.77	3.51	3.51	4.27	4.27	
900	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.77	2.01	3.51	2.77	4.27	2.77
1000	2.77	2.01	2.01	2.01	2.01	2.01	2.77	2.01	2.77	2.01	4.27	2.77	2.77E	2.77
1200	2.77	2.77	2.01	2.01	2.77	2.01	2.77	2.77	3.51	2.77	2.77E	2.77	3.51E	2.77
1400	2.77	2.77	2.77	2.01	2.77	2.01	2.77	2.77	4.27	2.77	3.51E	2.77	3.51E	3.51E
1600	3.51	2.77	3.51	2.01	3.51	2.77	3.51	2.77	4.27E	2.77	4.27E	3.51E	NB	3.51E
1800	Z3.51	2.77	3.51	2.01	3.51	2.77	4.27	2.77	NB	2.77	NB	3.51E	NB	3.51E
2000	Z4.27	2.77	4.27	2.01	4.27	2.77	NB	2.77	NB	3.51	NB	3.51E	NB	3.51E
2200	Z4.27	2.77	4.27	2.77	4.27	2.77	NB	2.77	NB	3.51E	NB	3.51E	NB	3.51E
2400	NB	2.77	NB	2.77	NB	2.77	NB	3.51	NB	3.51E	NB	3.51E	NB	4.27E
2700	NB	Z2.77	NB	2.77	NB	3.51	NB	3.51	NB	4.27E	NB	4.27E	NB	NB
3000		Z3.51		2.77		3.51		4.27		NB		NB		NB
3300		Z4.27		3.51		4.27		NB		NB		NB		NB
3600		Z4.27		3.51		NB		NB		NB		NB		NB

Note:

** 38 mm x 6.5 mm corrugations shall be used in lieu of 68 mm x 13 mm for 250 mm diameters

E Elongate in according to Article 542.04

NB Use uncoated corrugated steel structural plate pipe according to Section 541

Z 450 mm minimum fill

(ENGLISH)

TABLE IB: THICKNESS OF CORRUGATED STEEL PIPE FOR THE RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 2 2/3" x 1/2" AND 3" x 1" CORRUGATIONS

	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6		Type 7	
Nominal Diameter in.	Fill Height: 3' and less 1'-0" min. fill over pipe		Fill Height: Greater than 3' Not exceeding 10'		Fill Height: Greater than 10' Not exceeding 15'		Fill Height: Greater than 15' Not exceeding 20'		Fill Height: Greater than 20' Not exceeding 25'		Fill Height: Greater than 25' Not exceeding 30'		Fill Height: Greater than 30' Not exceeding 35'	
	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"
**10	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
12	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
15	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
18	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
21	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
24	0.079		0.079		0.079		0.079		0.079		0.079		0.109	
30	0.079		0.079		0.079		0.079		0.079		0.109		0.138	
36	0.079	0.079	0.079	0.07	0.079	0.079	0.079	0.079	0.109	0.079	0.138	0.109	0.168	0.109
42	0.109	0.079	0.079	0.07	0.079	0.079	0.109	0.079	0.109	0.079	0.168	0.109	0.109E	0.109
48	0.109	0.109	0.079	0.07	0.109	0.079	0.109	0.109	0.138	0.109	0.109E	0.109	0.138E	0.109
54	0.109	0.109	0.109	0.07	0.109	0.079	0.109	0.109	0.168	0.109	0.138E	0.109	0.138E	0.138E
60	0.138	0.109	0.109	0.07	0.109	0.109	0.138	0.109	0.138E	0.109	0.168E	0.138	0.168E	0.138E
66	0.138	0.109	0.138	0.07	0.138	0.109	0.138	0.109	0.168E	0.109	0.168E	0.138E	NB	0.138E
72	Z0.138	0.109	0.138	0.07	0.138	0.109	0.168	0.109	NB	0.109	NB	0.138E	NB	0.138E
78	Z0.168	0.109	0.168	0.07	0.168	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.138E
84	Z0.168	0.109	0.168	0.10	0.168	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.138E
90	NB	0.109	NB	0.10	NB	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.138E
96	NB	0.109	NB	0.10	NB	0.109	NB	0.138	NB	0.138	NB	0.138E	NB	0.168E
102	NB	Z0.109	NB	0.10	NB	0.109	NB	0.138	NB	0.138	NB	0.168E	NB	0.168E
108	NB	Z0.109	NB	0.10	NB	0.138	NB	0.138	NB	0.168	NB	0.168E	NB	NB
114		Z0.138		0.10		0.138		0.168		0.168		NB		NB
120		Z0.138		0.10		0.138		0.168		N		NB		NB
126		Z0.138		0.13		0.168		0.168		N		NB		NB
132		Z0.168		0.13		0.168		N		N		NB		NB
138		Z0.168		0.13		0.168		N		N		NB		NB
144		Z0.168		0.13		NB		N		N		NB		NB

Note: 125 mm x 25 mm Metric Corrugations may be used in lieu of 3"x1" Corrugations

** 1 1/2" x 1/4" corrugations shall be used in lieu of 2 2/3" x 1/2" f or 6", 8" and 10" diameters

E Elongate in accordance with Article 542.04

NB Use uncoated corrugated steel structural plate pipe in accordance with Section 541

Z 1'-6" minimum fill

TABLE IC: THICKNESS OF CORRUGATED ALUMINUM ALLOY PIPE FOR RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 68 mm x 13 mm AND 75 mm x 25 mm CORRUGATIONS

Nominal Diameter mm	Type 1 Fill Height: 1 m and less 0.3 m min. fill over pipe		Type 2 Fill Height: Greater than 1 m Not exceeding 3 m		Type 3 Fill Height: Greater than 3 Not exceeding 4.5 m		Type 4 Fill Height: Greater than m Not exceeding 6.0 m		Type 5 Fill Height: Greater than 4.5 m Not exceeding 7.5 m		Type 6 Fill Height: Greater than 6.0 m Not exceeding 9.0 m		Type 7 Fill Height: Greater than 7.5 m Not exceeding 10.5 m	
	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm	68mm x 13mm	75mm x 25mm
250	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
300	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
400	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
450	1.52		1.52		1.52		1.52		1.52		1.52		2.67	
500	1.52		1.52		1.52		1.52		1.52		2.67		3.43	
600	1.91		1.91		1.91		1.91		2.67		2.67		4.17	
700	2.67		1.91		2.67		2.67		2.67		3.43		2.67E	
800	2.67	2.67	2.67	1.91	2.67	1.91	2.67	2.67	4.17	2.67	3.43E	3.43	3.43E	X
900	2.67	2.67	2.67	1.91	2.67	1.91	2.67	2.67	4.17	2.67	3.43E	3.43	3.43E	X
1000	3.43	2.67	2.67	1.91	2.67	1.91	3.43	2.67	3.43E	2.67	4.17E	3.43	4.17E	X
1200	3.43	2.67	2.67	1.91	3.43	2.67	4.17	2.67	4.17E	2.67	X	X	X	X
1400	4.17	2.67	3.43	1.91	4.17	2.67	X	2.67	X	3.43	X	X	X	X
1600	X	2.67	4.17	2.67	X	2.67	X	2.67	X	X	X	X	X	X
1800	X	3.43	X	2.67	X	2.67	X	3.43	X	X	X	X	X	X
2000	X	3.43	X	2.67	X	3.43	X	3.43	X	X	X	X	X	X
2200	X	4.17	X	2.67	X	3.43	X	4.17	X	X	X	X	X	X
2400	X	X	X	3.43	X	4.17	X	X	X	X	X	X	X	X
2700	X	X	X	4.17	X	X	X	X	X	X	X	X	X	X
3000	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note:
E Elongate according to Article 542.04
X Use either steel or concrete pipe
Z 450 mm minimum fill

(ENGLISH)

TABLE IC: THICKNESS OF CORRUGATED ALUMINUM ALLOY PIPE FOR RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 2 2/3" x 1/2" AND 3" x 1" CORRUGATIONS

Nominal Diameter In.	Type 1 Fill Height: 3' and less 1'-0" min. fill over pipe		Type 2 Fill Height: Greater than 3' Not exceeding 10'		Type 3 Fill Height: Greater than 10' Not exceeding 15'		Type 4 Fill Height: Greater than 15' Not exceeding 20'		Type 5 Fill Height: Greater than 20' Not exceeding 25'		Type 6 Fill Height: Greater than 25' Not exceeding 30'		Type 7 Fill Height: Greater than 30' Not exceeding 35'	
	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3 "x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"
10	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
12	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
15	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
18	0.060		0.060		0.060		0.060		0.060		0.060		0.105	
21	0.060		0.060		0.060		0.060		0.060		0.105		0.135	
24	0.075		0.075		0.075		0.075		0.105		0.105		0.164	
30	0.105	0.10	0.075	0.075	0.105	0.075	0.105	0.105	0.105	0.105	0.135E	0.105	0.105E	X
36	0.105	0.10	0.105	0.075	0.105	0.075	0.105	0.105	0.164	0.105	0.135E	0.135	0.135E	X
42	0.135	0.10	0.105	0.075	0.105	0.075	0.135	0.105	0.135E	0.105	0.164E	0.135	0.164E	X
48	0.135	0.10	0.105	0.075	0.135	0.105	0.164	0.105	0.164E	0.105	X	X	X	X
54	0.164	0.10	0.135	0.075	0.164	0.105	X	0.105	X	0.135	X	X	X	X
60	Z0.164	0.10	0.135	0.105	X	0.105	X	0.105	X	X	X	X	X	X
66	X	0.10	0.164	0.105	X	0.105	X	0.105	X	X	X	X	X	X
72	X	0.13	X	0.105	X	0.105	X	0.135	X	X	X	X	X	X
78	X	0.13	X	0.105	X	0.135	X	0.135	X	X	X	X	X	X
84	X	0.16	X	0.105	X	0.135	X	0.164	X	X	X	X	X	X
90	X	0.16	X	0.135	X	0.164	X	X	X	X	X	X	X	X
96	X	X	X	0.135	X	0.164	X	X	X	X	X	X	X	X
102	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
108	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
114	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
120	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note:

E Elongate according to Article 542.04

X Use either steel or concrete pipe

Z 1'-6" minimum fill

TABLE - IIA: THICKNESS FOR CORRUGATED STEEL PIPE ARCHES AND CORRUGATED ALUMINUM ALLOY PIPE ARCHES FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size Mm	Corrugated Steel Pipe Arch (68 mm x 13 mm) mm		Corrugated Steel Pipe Arch (75 mm x 25 mm) mm		Corrugated Aluminum Pipe Arch (68 mm x 13 mm) mm		Type 1			Type 2			Type 3		
							Min. Fill Height	Fill Height Not Exceeding 1.0 m			Fill Height Greater than 1.0 m Not Exceeding 3 m			Fill Height Greater than 3 m Not Exceeding 4.5 m	
								Steel	Aluminum		Steel	Aluminum		Steel	Aluminum
	Span	Rise	Span	Rise	Span	Rise	Steel & Alum	68 x 13 mm	75 x 25 mm	68 x 13 mm	68 x 13 mm	75 x 25 mm	68 x 13 mm	68 x 13 mm	75 x 25 mm	68 x 13 mm
400	460	340			460	340	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
450	510	380			510	380	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
500	560	420			560	420	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
600	680	500			680	500	0.5 m	2.01		1.91	2.01		1.91	2.01		1.91
700	800	580			800	580	0.5 m	2.01		2.67	2.01		2.67	2.01		2.67
800	910	660			910	660	0.5 m	2.01		2.67	2.01		2.67	2.01		2.67
900	1030	740	1016	787	1030	740	0.5 m	2.01	2.01	2.67	2.01	2.01	2.67	2.01	2.01	2.67
1000	1150	820	1168	914	1150	820	0.5 m	2.77	2.01	3.43	2.01	2.01	2.67	2.77	2.01	3.43
1200	1390	970	1330	1030	1390	970	0.5 m	2.77	2.01	4.17	2.77	2.01	3.43	2.77	2.01	4.17
1400	1630	1120	1550	1200	1630	1120	0.5 m	2.77	2.01	4.17	2.77	2.01	3.43	2.77	2.01	4.17
1600	1880	1260	1780	1360	1880	1260	0.5 m	4.27	2.77	X	4.27	2.01	X	4.27	2.77	X
1800	2130	1400	2010	1500	2130	1400	0.5 m	4.27	2.77	X	4.27	2.77	X	4.27	2.77	X
2000			2230	1700			0.5 m		2.77			2.77			2.77	
2200			2500	1830			0.5 m		2.77			2.77			2.77	
2400			2800	1950			0.5 m		3.51			2.77			3.51	
2700			3300	2080			0.5 m		3.51			3.51			4.27	
3000			3650	2280			0.5 m		4.27			4.27			4.27	

NOTES: The Type 1 and 3 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 290 kN/m
The Type 2 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 192 kN/m^2
This minimum bearing capacity will be determined by the Engineer in the field.
X Use either steel or concrete.

(ENGLISH)

TABLE - IIA: THICKNESS FOR CORRUGATED STEEL PIPE ARCHES AND CORRUGATED ALUMINUM ALLOY PIPE ARCHES FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size In.	Corrugated Steel Pipe Arch (2 2/3" x 1/2") In.		Corrugated Steel Pipe Arch (3" x 1") In.		Corrugated Aluminum Pipe Arch (2 2/3" x 1/2") In.		Type 1				Type 2				Type 3			
							Min. Fill Height	Fill Height Not Exceeding 3'			Fill Height Greater than 3' Not Exceeding 10'				Fill Height Greater than 10' Not Exceeding 15'			
	Span	Rise	Span	Rise	Span	Rise	Steel & Alum	Steel		Aluminum	Steel		Aluminum		Steel		Aluminum	
								2 2/3 x 1/2 in.	3 x 1 2 in.	2 2/3 x 1/2 in.	2 2/3 x 1/2 in.	3 x 1 2 in.	2 2/3 x 1/2 in.		2 2/3 x 1/2 in.	3 x 1 2 in.	2 2/3 x 1/2 in.	
15	17	13			17	13	1'-0"	0.064		0.060	0.064		0.060		0.064		0.060	
18	21	15			21	15	1'-0"	0.064		0.060	0.064		0.060		0.064		0.060	
21	24	18			24	18	1'-0"	0.064		0.060	0.064		0.060		0.064		0.060	
24	28	20			28	20	1'-6"	0.079		0.075	0.079		0.075		0.079		0.075	
30	35	24			35	24	1'-6"	0.079		0.105	0.079		0.105		0.079		0.105	
36	42	29	40	31	42	29	1'-6"	0.079	0.079	0.105	0.079	0.079	0.105		0.079	0.079	0.105	
42	49	33	46	36	49	33	1'-6"	0.109	0.079	0.135	0.079	0.079	0.105		0.109	0.079	0.135	
48	57	38	53	41	57	38	1'-6"	0.109	0.079	0.164	0.109	0.079	0.135		0.109	0.079	0.164	
54	64	43	60	46	64	43	1'-6"	0.109	0.079	X	0.109	0.079	0.164		0.138	0.109	X	
60	71	47	66	51	71	47	1'-6"	0.138	0.109	X	0.138	0.079	X		0.138	0.109	X	
66	77	52	73	55	77	52	1'-6"	0.168	0.109	X	0.168	0.079	X		0.168	0.109	X	
72	83	57	81	59	83	57	1'-6"	0.168	0.109	X	0.168	0.109	X		0.168	0.109	X	
78			87	63			1'-6"		0.109			0.109				0.109		
84			95	67			1'-6"		0.109			0.109				0.109		
90			103	71			1'-6"		0.109			0.109				0.109		
96			112	75			1'-6"		0.138			0.109				0.138		
102			117	79			1'-6"		0.138			0.109				0.138		
108			128	83			1'-6"		0.138			0.138				0.168		
114			137	87			1'-6"		0.168			0.138				0.168		
120			142	91			1'-6"		0.168			0.138				0.168		

NOTES: The Type 1 and 3 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 3 tons per square foot. The Type 2 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 2 tons per square foot. This minimum bearing capacity will be determined by the Engineer in the field.

The 125 mm x 25 mm Metric Corrugations for Corrugated Steel Pipe Arch may be used in lieu of the 3" x 1" Corrugations.

X Use either steel or concrete.

TABLE - IIB: CLASSES OF REINFORCED CONCRETE ELLIPTICAL AND REINFORCED CONCRETE ARCH PIPE FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size	Reinforced Concrete Elliptical Pipe mm		Reinforced Concrete Arch Pipe mm		Min. Fill Height	Type 1 Fill Height Not Exceeding 1.0 m		Type 2 Fill Height Greater than 1.0 m Not Exceeding 3 m		Type 3 Fill Height Greater than 3 m Not Exceeding 4.5 m	
Mm	Span	Rise	Span	Rise	RCCP HE & A	HE	Arch	HE	Arch	HE	Arch
375	584	356	457	279	0.4 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
450	584	356	559	343	0.4 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
525	762	483	660	394	0.3 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
600	762	483	724	457	0.3 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
686	864	559	921	572	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
750	965	610	921	572	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
900	1143	737	1111	676	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
1050	1346	864	1299	795	0.3 m	HE-II	A-II	HE-I	A-II	HE-III	A-III
1200	1524	965	1486	914	0.3 m	HE-II	A-II	HE-I	A-II	HE-III	A-III
1350	1727	1092	1651	1016	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1500	1930	1219	1854	1143	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1676	2108	1346	2235	1372	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1800	2311	1473	2235	1372	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III

(ENGLISH)
TABLE - IIB: CLASSES OF REINFORCED CONCRETE ELLIPTICAL AND REINFORCED CONCRETE ARCH PIPE FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size	Reinforced Concrete Elliptical Pipe In.		Reinforced Concrete Arch Pipe In.			Type 1		Type 2		Type 3	
					Min. Fill Height	Fill Height Not Exceeding 3'		Fill Height Greater than 3' Not Exceeding 10'		Fill Height Greater than 10' Not Exceeding 15'	
In.	Span	Rise	Span	Rise	RCCP HE & A	HE	Arch	HE	Arch	HE	Arch
15	23	14	18	11	1'-3"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
18	23	14	22	13 1/2	1'-3"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
21	30	19	26	15 1/2	1'-0"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
24	30	19	28 1/2	18	1'-0"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
27	34	22	36 1/4	22 1/2	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
30	38	24	36 1/4	22 1/2	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
36	45	29	43 3/4	26 5/8	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
42	53	34	51 1/8	31 5/16	1'-0"	HE-II	A-II	HE-I	A-II	HE-III	A-III
48	60	38	58 1/2	36	1'-0"	HE-II	A-II	HE-I	A-II	HE-III	A-III
54	68	43	65	40	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
60	76	48	73	45	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
66	83	53	88	54	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
72	91	58	88	54	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III

PIPE CULVERTS
TABLE - IIIA: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (mm)	Type 1 Fill Height: 1 m and less than 0.3 m min. Cover							Type 2 Fill Height: Greater than 1 m, not Exceeding 3.0 m						
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW
250	X	NA	NA	NA	X	NA	NA	X	*	NA	NA	X	NA	NA
300	X	X	X	X	X	X	NA	X	X	X	X	X	X	NA
375	X	X	X	X	NA	X	NA	X	X	X	X	NA	X	NA
450	X	X	X	X	X	X	X	X	X	X	X	X	X	X
525	X	X	X	X	NA	NA	X	X	X	X	X	NA	NA	X
600	X	X	X	X	X	X	X	X	X	X	X	X	X	X
750	X	X	X	X	X	X	X	X	X	X	X	X	X	X
900	X	X	X	X	X	X	X	X	X	X	X	X	X	X

PIPE CULVERTS
TABLE - IIIB: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (mm)	Type 3 Fill Height: Greater than 3.0 m and not Exceeding4.5 m						Type 4 Fill Height: Greater than 4.5 m, not Exceeding 6.0 m				
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	
250	X	*	NA	NA	X	NA	X	*	NA	NA	
300	X	X	X	X	X	NA	X	X	X	X	
375	X	X	X	X	NA	NA	X	X	X	X	
450	X	X	X	X	X	X	X	X	X	X	
525	X	X	X	X	NA	X	X	X	X	X	
600	X	X	X	X	X	X	X	X	X	X	
750	X	X	X	X	X	X	X	X	X	X	
900	X	X	X	X	X	X	X	X	X	X	

X Indicates this diameter pipe may be used.
NA Not acceptable
PVC Polyvinyl Chloride (PVC) Pipe
CPVC Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304 Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE Polyethylene (PE) Pipe With a Smooth Interior
CPE Corrugated Polyethylene (PE) Pipe with a Smooth Interior
PEPW Polythylene (PE) Profile Wall Pipe
* May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

PIPE CULVERTS

TABLE - IIIC: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (mm)	Type 5 Fill Height: Greater Than 6.0 m Not Exceeding 7.5 m				Type 6 Fill Height: Greater Than 7.5 m Not Exceeding 9.0 m				Type 7 Fill Height: Greater Than 9.0 m Not Exceeding 10.5 m	
	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	
250	X	*	NA	NA	X	*	NA	NA	X	
300	X	X	X	X	X	X	X	X	X	
375	X	X	X	X	X				X	
450	X	X	X	X	X				X	
525	X	X	X	X	X				X	
600	X	X	X	X	X				X	
750	X				X				X	
900	X				X				X	

X	Indicates this diameter pipe may be used.
N A	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smoother Interior
PEPW	Polythylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

PIPE CULVERTS (ENGLISH)
TABLE - IIIA: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (in.)	Type 1 Fill Height: 3 ft and less with 1 ft min. Cover							Type 2 Fill Height: Greater than 3 ft, not Exceeding 10 ft.						
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW
10	X	NA	NA	NA	X	NA	NA	X	*	NA	NA	X	NA	NA
12	X	X	X	X	X	X	NA	X	X	X	X	X	X	NA
15	X	X	X	X	NA	X	NA	X	X	X	X	NA	X	NA
18	X	X	X	X	X	X	X	X	X	X	X	X	X	X
21	X	X	X	X	NA	NA	X	X	X	X	X	NA	NA	X
24	X	X	X	X	X	X	X	X	X	X	X	X	X	X
30	X	X	X	X	X	X	X	X	X	X	X	X	X	X
36	X	X	X	X	X	X	X	X	X	X	X	X	X	X

PIPE CULVERTS (ENGLISH)
TABLE - IIIB: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (in.)	Type 3 Fill Height: Greater than 10 ft and not Exceeding 15 ft						Type 4 Fill Height: Greater than 15 ft not Exceeding 20 ft			
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304
10	X	*	NA	NA	X	NA	X	*	NA	NA
12	X	X	X	X	X	NA	X	X	X	X
15	X	X	X	X	NA	NA	X	X	X	X
18	X	X	X	X	X	X	X	X	X	X
21	X	X	X	X	NA	X	X	X	X	X
24	X	X	X	X	X	X	X	X	X	X
30	X	X	X	X	X	X	X	X	X	X
36	X	X	X	X	X	X	X	X	X	X

X	Indicates this diameter pipe may be used.
N A	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smooth Interior
PEPW	Polythylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

PIPE CULVERTS (ENGLISH)
TABLE - IIIC: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter (in.)	Type 5 Fill Height: Greater Than 20 ft Not Exceeding 25 ft					Type 6 Fill Height: Greater than 25 ft Not Exceeding 30 ft				Type 7 Fill Height: Greater than 30 ft, Not Exceeding 35 ft	
	PVC	CPVC	PVCPW -794	PVCPW -304		PVC	CPVC	PVCPW -794	PVCPW -304	PVC	
10	X	*	NA	NA		X	*	NA	NA	X	
12	X	X	X	X		X	X	X	X	X	
15	X	X	X	X		X				X	
18	X	X	X	X		X				X	
21	X	X	X	X		X				X	
24	X	X	X	X		X				X	
30	X					X				X	
36	X					X				X	

X	Indicates this diameter pipe may be used.
N A	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smooth Interior
PEPW	Polyethylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

542.04 Method I Construction. Unless otherwise permitted in writing by the Engineer because of conditions encountered in construction, all pipe culverts, except entrance culverts, shall be constructed according to the following requirements:

(a) Removal and Replacement of Unstable or Unsuitable Material or Rock.

Where unstable material such as soft or spongy soil, unsuitable material or rock in either ledge or boulder formation is encountered at locations along the line of the pipe culvert and at the grade established for the culvert, the material or rock shall be removed and replaced before proceeding with the construction.

The unstable and unsuitable material shall be removed to a depth determined by the Engineer and for a width of one diameter (or equivalent diameter) of the pipe on each side of the pipe culvert, and replaced with granular material meeting the approval of the Engineer. Rock shall be removed to an elevation 300 mm (12 in.) lower than the bottom of the pipe or to a depth equal to 40 mm/m (1/2 in./ft) of ultimate fill height over the top of the pipe culvert, whichever is the greater depth, and for a width as specified in (b) below, and replaced with moist fine aggregate meeting the approval of the Engineer. Replacement material shall be placed in 200 mm (8 in.) layers, loose measurement, and compacted to the satisfaction of the Engineer by mechanical means.

(b) Trenching. Pipe culverts shall be constructed in trenches, excavated either in embankments and/or natural ground.

When practical to do so, the Contractor shall excavate a diversion channel for the water. The channel cut and shape and its backfilling with granular material shall meet the approval of the Engineer. This work will not be paid for as a separate item, but shall be considered as included in the contract unit price bid for the item of pipe culvert involved and no additional compensation will be allowed.

When all or a portion of a pipe will be in fill, the embankment, or a portion thereof, shall be constructed prior to excavating the trench. The embankment shall be constructed to a height which will provide approximately 300 mm (12 in.) of cover over the pipes, except that in no case, even when pipes with a vertical height greater than 1.2 m (4 ft) are to be installed, shall the height of the embankment constructed exceed 1.5 m (5 ft) or result in a finished trench depth exceeding 1.5 m (5 ft). The width of the top of the embankment shall not be less than 4 m (13 ft) on each side of the pipe culvert, measured at right angles to its centerline, and the longitudinal slopes shall not be steeper than 1:6 (V:H). The embankment shall be constructed according to the requirements of Section 205, except the material shall be select material from excavation or borrow, meeting the approval of the Engineer.

Trenches shall be excavated to an elevation 100 mm (4 in.) below that of the bottom of the pipe and to a specified width on each side of the pipe (according to inside diameters or equivalent pipe diameters) of not more

than: 225 mm (9 in.) for pipe sizes up to 600 mm (24 in.), 300 mm (12 in.) for pipe sizes greater than 600 mm (24 in.) and up to 1.2 m (48 in.), and 450 mm (18 in.) for pipe sizes greater than 1.2 m (48 in.). Care should be exercised to maintain vertical faces while excavating the trench. If the width of the trench at the top of the trench exceeds the maximum horizontal dimension of the pipe by more than the above specified widths as a result of careless or faulty construction methods, that portion of the trench shall be corrected by the Contractor at his/her own expense by backfilling in 200 mm (8 in.) layers and again excavating the trench to the required width. The backfill material and its placement shall be the same as stipulated for the embankment.

(c) Preparation of Foundation. When the trench has been excavated for the entire length of the pipe culvert and any required removal and replacement of unstable or unsuitable material or rock has been completed, as specified in Article 542.04(a), the foundation for the pipe culvert shall be prepared.

Well compacted moist fine aggregate, at least 100 mm (4 in.) in depth below the pipe culvert, shall be placed the entire width of the trench and for the length of the pipe culvert, except that well compacted impervious material shall be used for the outer 1 m (3 ft) at each end of the pipe. When the trench has been widened by the removal and replacement of unstable or unsuitable material, the foundation material shall be placed for a width not less than the above specified widths on each side of the pipe. The fine aggregate and impervious material shall meet the approval of the Engineer and shall be compacted to the Engineer's satisfaction by mechanical means.

When pipe having bells or hubs is used, cross trenches not more than 50 mm (2 in.) wider than the bell or hub, shall be excavated to provide uniform bearing along the length of the pipe.

(d) Laying Pipe. No pipe culvert shall be placed until the trench and the prepared foundation have been approved by the Engineer.

The pipe shall be laid so that the flow line of the finished culvert will be at the grade shown on the plans or established by the Engineer. Laying of pipes for the pipe culvert shall commence at the outlet end, with the spigot ends of the pipe pointing in the direction of the flow, and proceed toward the inlet end with pipes abutting, and true to line and grade.

The ends of the pipe shall be carefully cleaned before the pipes are placed and the pipes shall be placed to avoid unnecessary handling on the foundation. As each length of the pipe is laid, the ends of the pipe shall be protected to prevent the entrance of any material. The pipes shall be fitted and matched so that when laid in the work, they will form a culvert with a smooth, uniform invert.

When corrugated steel or aluminum alloy culvert pipe (including bituminous coated steel or aluminum and precoated steel) is used, the longitudinal lap shall be placed at the sides and separate sections of pipe shall be joined with tightly drawn, approved connectors.

Circular corrugated steel or aluminum alloy culvert pipe (including bituminous coated steel or aluminum and precoated steel) that are specified as elongated in Table IB or IC shall be elongated vertically five percent out of a round before any fill is placed. A tolerance in elongation of ± 0.75 percent will be permitted. The pipe, except for bituminous coated corrugated steel or aluminum culvert pipe, shall be elongated by one of the following methods:

(1) Deformation during fabrication.

(2) Elongation by the use of wires, rods or straps during fabrication.

(3) Elongation at the time of installation by the use of vertical struts, wedged or jacked inside the pipe in a manner approved by the Engineer.

Bituminous coated corrugated steel or aluminum circular culvert pipe shall be elongated by either method (1) or (2) prior to coating.

Pipe elongated by the manufacturer shall be marked to show the top. Pipe elongated by deformation during fabrication shall be stored, transported and handled in such a manner so that at the time of installation the pipe shall have retained its elongation.

When the pipe is elongated by method (2) or (3), it shall be installed in a manner that will permit the gradual reduction of elongation as the fill over the pipe is placed. This reduction in elongation shall be as directed by the Engineer and may be accomplished by the use of softwood compression caps when struts or jacks are used, or by the use of turnbuckles or other devices when wires, rods or straps are used.

After the fill has been placed and compacted, all struts, wires, rods or straps shall be removed, and any holes in the pipe resulting from their use shall be plugged in a manner satisfactory to the Engineer. Heavy asphaltic or tar material, or other material, or a device meeting the approval of the Engineer may be used to plug the holes.

No strutting or elongation will be permitted on corrugated steel or aluminum (including bituminous coated steel or aluminum and precoated steel) pipe arches.

All joints in concrete culverts shall be sealed with preformed flexible gasket or mastic joint sealer conforming to Sections 1056 or 1055 or external sealing bands conforming to Section 1057. When mastic joint sealer is used, the material shall completely fill the joint after the pipes have been brought together. Each section of pipe shall be pushed or pulled as tight as reasonably possible to the section in place to ensure tight joints. Pipe having a diameter or equivalent diameter greater than 1 m (42 in.) shall be set or "brought home" with a winch, come-a-long or other positive means.

All handling holes in concrete culverts shall be filled with a precast plug, sealed and covered with mastic or mortar.

(e) Backfilling. As soon as the condition of the pipe culvert will permit, the entire width of the trench shall be backfilled with moist fine aggregate meeting the gradations specified in Article 1003.04 to a height of at least the elevation of the center of the pipe. The fine aggregate shall be placed longitudinally along the pipe culvert, except at the outer 1 m (3 ft) at each end of the culvert which shall be backfilled with impervious material. The elevation of the backfill material on each side of the pipe shall be the same. The space under the pipe shall be completely filled. The backfill material, fine aggregate and impervious material shall be placed in 200 mm (8 in.) layers, loose measurement. When using PVC, PE, or corrugated metal pipe, the pipe shall be backfilled with a moist fine aggregate 300 mm (1 ft) over the top of the pipe and compacted to a minimum of 85 percent of standard lab density by mechanical means. When reinforced concrete pipes are used, the backfill shall be compacted to a minimum of 85 percent of standard lab density when the trench is within 600 mm (2 ft) of the pavement structure. The materials used for backfilling shall meet the approval of the Engineer.

When using PVC, PE, or corrugated metal pipe a minimum of 300 mm (1 ft) of cover from the top of the pipe to the top of the subgrade will be required.

The installed pipe and its embedment shall not be disturbed when using movable trench boxes and shields.

The remainder of the trench shall be backfilled with select material, from excavation or borrow, free from large or frozen lumps, clods or rock, meeting the approval of the Engineer. The material shall be placed in layers not exceeding 200 mm (8 in.) in depth, loose measurement and compacted to 95 percent of the standard laboratory density. Compaction shall be obtained by use of mechanical tampers or with approved vibratory compactors. Before compacting, each layer shall be wetted or dried to bring the moisture content within the limits of 80 to 110 percent of optimum moisture content determined according to AASHTO T 99 (Method C). The backfill material on each side of the pipe culvert shall be kept at approximately the same elevation. If the Contractor, at his/her option, uses fine aggregate instead of select material, it shall be compacted by mechanical means to the satisfaction of the Engineer, and no additional compensation will be allowed.

When the trench has been widened for the removal and replacement of unstable or unsuitable material, the backfilling with moist fine aggregate and impervious material, to at least the elevation of the center of the pipe, will be required for a width of at least the specified widths on each side of the pipe. The remaining width of each layer may be backfilled with select material. Each 200 mm (8 in.) layer for the entire trench width shall be completed before beginning the placement of the next layer.

(f) Embankment. After backfilling to the top of the trench for the entire length or portion of the length constructed by this method, and when the top of the trench is not 300 mm (12 in.) over the top of the pipe, the embankment shall be constructed to an elevation of 300 mm (1 ft) above the top of the pipe. While constructing the embankment, no heavy earth-moving equipment will be permitted within 1.5 m (4 ft) of either side of the pipe culvert. The

Contractor shall not introduce any loads upon the pipe culvert, other than equipment permitted by the Engineer for the construction of the embankment to the required height, until the Contractor has constructed additional embankment as specified.

The embankment shall be constructed according to Section 205, except the material shall be select material, from excavation or borrow, meeting the approval of the Engineer. The select material to within 1.5 m (4 ft) of each side of the pipe culvert shall be compacted by mechanical means. The embankment shall be constructed to the width and longitudinal slopes specified in Article 542.04 (b).

(g) Additional Embankment. After the trench has been backfilled and embankment constructed to an elevation of 300 mm (12 in.) over the top of the pipe culvert, additional embankment shall be constructed before the Contractor will be permitted to introduce any loads upon the pipe culvert. The required cover, including any embankment cover over the pipe and additional embankment, shall be sufficient for the maximum load, including the weight of equipment, which the Contractor proposes to operate or move across the pipe culvert. The total cover required for various loadings shall be as shown in Table III Wheel Loads and Total Cover.

Additional embankment shall be constructed according to Section 205. Its width on each side of the pipe culvert shall be 4 m (13 ft) and the longitudinal slopes shall not be steeper than 1:6 (V:H). The width of the additional embankment, measured along the pipe culvert, shall be the actual fill width indicated on the cross sections at the elevation required in the above table or sufficient to accommodate two-way traffic of the Contractor's grading operations and so no equipment is operated within 3 m (10 ft) of either shoulder line, whichever is the least.

Where the elevation of the additional embankment is above the elevation of the finished embankment, the Contractor shall remove it at the time of final grading operations.

Where the elevation of the finished embankment is higher than the additional embankment, the Contractor shall scarify the surface of the slopes and the top of the embankment.

(h) Deflection Testing for Pipe Culverts. All PE and PVC pipe culverts will be tested for deflection not less than 30 days after the pipe is installed and the backfill compacted.

TABLE III

		Wheel Load (kiloNewtons)										
		9	44	89	133	178	223	267	311	356	400	445
	Nominal or Equivalent Diameter (mm)	Total Cover (meters)										
Type 1 & 4	200 to 2700, incl.	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.2
Type 2 & 3	200 to 2700, incl.	0.6	0.9	1.2	1.7	2.1	2.6	3.0	3.5	4.0	4.3	4.6
Type 5 & 6	200 to 1800, incl.	0.3	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.5	1.7	1.8
	1950 to 2700, incl.	0.3	0.5	0.6	0.9	1.1	1.2	1.4	1.5	1.5	1.7	1.8
Type 7	200 to 1800, incl.	0.3	0.5	0.6	0.8	0.9	0.9	1.1	1.1	1.2	1.2	1.4
	1950 to 2700, incl.	0.3	0.3	0.6	0.6	0.9	0.9	1.1	1.1	1.2	1.2	1.4

(ENGLISH)
TABLE III

	Nominal or Equivalent Diameter (in.)	Wheel Load (tons) 1	5	10	15	20	25	30	35	40	45	50
		Total Cover (feet)										
Type 1 & 4	8" to 108", incl.	1.0	2.0	3.0	4.0	5.0	5.5	6.5	7.5	8.5	9.5	10.5
Type 2 & 3	8" to 108", incl.	2.0	3.0	4.0	5.5	7.0	8.5	10.0	11.5	13.0	14.0	15.0
Type 5 & 6	8" to 72", incl.	1.0	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.0	5.5	6.0
	78" to 108", incl.	1.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.0	5.5	6.0
Type 7	8" to 72", incl.	1.0	1.5	2.0	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5
	78" to 108", incl.	1.0	1.0	2.0	2.0	3.0	3.0	3.5	3.5	4.0	4.0	4.5

The height of additional embankment constructed over Pipe Culverts, Special, shall be as specified.

Additional embankment shall be constructed according to Section 205. Its width on each side of the pipe culvert shall be 4 m (13 ft) and the longitudinal slopes shall not be steeper than 1:6 (V:H). The width of the additional embankment, measured along the pipe culvert, shall be the actual fill width indicated on the cross sections at the elevation required in the above table or sufficient to accommodate two-way traffic of the Contractor's grading operations and so that no equipment is operated within 3 m (10 ft) of either shoulder line, whichever is the least.

Where the elevation of the additional embankment is above the elevation of the finished embankment, the Contractor shall remove it at the time of his/her finish grading operations.

Where the elevation of the finished embankment is higher than that of the additional embankment, the Contractor shall scarify the surface of the slopes and the top of the embankment.

542.05 Method II Construction. Method II Construction may be used to construct pipe culverts, except entrance culverts, only when specified or when physical conditions are encountered in construction which make the use of Method I Construction impractical and written permission is obtained from the Engineer. In Method II Construction, all or a portion of a pipe culvert may be constructed in a trench excavated in the existing ground prior to placement of the required embankment.

The construction procedures for Method II Construction shall be the same as previously specified in Article 542.04 for Method I Construction, except as follows:

(a) Trenching. Trenching shall be as specified in Article 542.04(b), except that the depth of the trench shall be such that the bottom elevation of the pipe will not be less than one-tenth of the diameter (or equivalent diameter) of the pipe below the top of the trench. When the elevation of the bottom of the pipe is less than the specified distance below the natural ground line, sufficient embankment shall be constructed to an elevation that will provide pipe embedment to at least one-tenth of the diameter (or equivalent diameter) of the pipe before the trench is excavated.

(b) Embankment. Embankment extending to an elevation of 300 mm (12 in.) over the top of the pipe shall be constructed according to the requirements of Article 542.04(f), except that the material up to the elevation of the center of the pipe and extending to a width of at least 450 mm (18 in.) on each side of the pipe, exclusive of the outer 1 m (3 ft) at each end of the pipe, shall consist of moist fine aggregate. At the outer 1 m (3 ft) at each end of the culvert, impervious material shall be used.

542.06 Method III Construction. Entrance culverts, either private or field, shall be constructed according to the following requirements:

(a) Trenching. Normally, trenching other than that necessary to place the pipe culvert to a depth equal to one-tenth of its external diameter will not be required. Additional trenching may be necessary to some cases due to the location of a pipe culvert. The trenching shall be performed as specified for Method II except as follows:

The trench shall be excavated only to the bottom of the pipe culvert and for a width sufficient to place the pipe. The bottom of the trench shall be shaped to approximately the size and shape of the pipe culvert.

(b) Preparation of Foundation. After the trench has been excavated for the entire length of the pipe culvert, and any necessary removal and replacement of unstable or unsuitable material or rock has been completed, the foundation for the pipe culvert shall be prepared as follows:

The bottom of the trench shall be shaped to substantially fit the exterior of the pipe. If necessary, material meeting the approval of the Engineer shall be used to fill depressions. The material comprising the foundation shall then be compacted to the satisfaction of the Engineer.

(c) Laying Pipe. No pipe culvert shall be placed in the trench until it and the foundation have been approved by the Engineer. The pipe shall be laid as specified for Method I construction.

(d) Placing Backfill in the Trench and/or Constructing Embankment. As soon as the condition of the pipe culvert will permit, the trench shall be backfilled and/or embankment constructed.

The material used shall be select material, meeting the approval of the Engineer, from excavation or borrow. The material shall be placed in 200 mm (8 in.) layers, loose measurement, and compacted to the satisfaction of the Engineer. Compaction shall be obtained by mechanical means or, when approved by the Engineer, hand tampers weighing not less than 4 kPa (0.6 psi) of tamping surface may be used. Special care shall be taken to completely fill the space under the pipe. The material shall be placed to an elevation one foot above the top of the pipe culvert or to the finished grade, whichever is the lesser height.

When embankment is being constructed, the material used for its construction shall be placed to a width, on each side of the pipe culvert, not less than one diameter of the pipe.

(e) Deflection testing for entrance culverts may be required at the option of the Engineer. When required, it shall be according to Article 542.04.

542.07 End Treatment. End treatment of pipe culverts shall consist of a cast-in-place reinforced concrete end section, a precast reinforced concrete flared end section, a metal end section of aluminum or steel, an inlet box for side slope or an inlet box for median slope. When an end treatment is required, it will be specified on the plans. When the type of end treatment to be used is specified on the plans, only that type shall be used. The installation of the end treatment shall consist of

furnishing and installing the end section complete in place, including end blocks, toe plates, excavating, and backfilling.

When the pipe is at a 15 degree skew or less with the roadway and the diameter is 2100 mm (84 in.) or less, if end treatment is required but the type of treatment is not specified on the plans, the Contractor shall have the option of using either a cast-in-place concrete headwall or a prefabricated end section of precast reinforced concrete or metal. If a prefabricated end section is used, it shall be of the same material as the pipe culvert, except for polyethylene (PE) and polyvinylchloride (PVC) pipe which shall be a metal end section.

(a) Cast-In-Place Reinforced Concrete End Section. Cast-in-place reinforced concrete end sections shall be constructed of Class SI Concrete according to the requirements of Section 503 and the details shown on the plans.

(b) Precast Reinforced Concrete Flared End Section. Precast reinforced concrete flared end sections shall be constructed according to the details shown on the plans and shall conform to the applicable requirements of AASHTO M 170M (M 170) Class III, Wall B reinforced concrete pipe. End blocks shall be either precast or cast in place, and shall be in proper position and backfilled according to the applicable paragraphs of Article 502.10 prior to the installation of the precast reinforced concrete flared end sections.

Grating for Precast Reinforced Concrete Flared End Sections. Grating shall be installed on precast reinforced concrete flared end sections at the location specified on the plans. The grating shall be fabricated and installed according to the details shown on the plans.

Structural steel shapes and plates shall conform to the requirements of Article 1006.04. Galvanized steel pipe shall conform to the requirements of Article 1006.27(b). Bolts, nuts and washers shall conform to the requirements of Article 1006.27(f).

Fabrication of the grating shall be completed and ready for assembly before galvanizing.

(c) Metal End Sections. Metal end sections shall be fabricated of aluminum or steel, and all component parts shall be of the same material. When steel end sections are used, the base metal, rivets and spelter coating shall conform to AASHTO M 36M (M 36). When aluminum end sections are used, the material shall conform to AASHTO M 196M (M 196). Toe plates shall be furnished and the metal thickness shall be the same as that used in the end section.

Fabrication shall be according to the dimensions and details shown on the plans. All 3-piece bodies shall have 2.77 mm (0.109 in.) sides and 3.51 mm (0.138 in.) center panels. Width of center panels shall be greater than 20 percent of the pipe periphery. Multiple panel bodies shall have lap seams which shall be tightly jointed with M10 (3/8 in.) rivets or bolts.

(d) Inlet Box for Side Slope, Median Slope and Median Ditch Check. Inlet boxes for side slopes, median slopes and median ditch checks shall be constructed of the sizes and locations and according to the standard details shown on the plans. Inlet Box for Side Slope shall be cast in place. Inlet Box for Median Slope and Inlet Box For Median Ditch Check shall be either cast in place or precast units.

If inlet boxes are cast in place, they shall be constructed of Class SI Concrete according to the applicable requirements of Section 503.

If precast units are used, they shall be fabricated of Class PC Concrete according to the applicable requirements of Section 504.

The minimum bar lap for both precast and cast-in-place units shall be 325 mm (13 in.).

The exposed edges of concrete shall be beveled 20 mm (3/4 in.) on both precast and cast-in-place units.

Galvanized steel pipe required for the construction of inlets shall meet the requirements of ASTM A 53, Grade B, Schedule 40, or approved equal. Galvanized U-bolts, nuts and washers shall meet the requirements of Article 1006.27(f). Steel plates shall meet the requirements of Article 1006.04, and shall be galvanized according to the requirements of AASHTO M 111 after fabrication.

Grating and frames required for Inlet Box for Median Ditch Check shall be steel or cast grating fabricated according to the details shown on the plans and shall be approved by the Engineer. Steel grating and frames shall conform to Article 1006.04 and shall be galvanized according to requirements of AASHTO M 111 after fabrication. Cast grating shall conform to Article 1006.15, Grade 60-40-18, or to Article 1006.14 and proof-load tested according to Federal Specifications RR-F-621. The proof-load shall be 110 kN (25,000 lb) on a 225 mm x 225 mm (9 in. x 9 in.) cast block. Cast frames shall conform to Article 1006.14. Cast grating and frames shall not be galvanized.

Pressure lock type steel grating and riveted steel grating with reticuline bars will be accepted for galvanizing according to the requirements of AASHTO M 111.

Steel grating shall seat firmly in the frame but shall not be secured to the frame. The grating shall be cut in such manner that all riveted or welded connections are left in tact. The edges of the main bearing bars shall be laterally supported by transverse bars. Grating shall be approved by the Engineer. All welding shall be done according to the applicable requirements of Section 505, and shall be done before galvanizing.

For flush inlet boxes for medians, steel grating shall have the main bearing bars running parallel to the centerline of the median. The main bearing bars shall be as specified or shall be 89 mm (3 1/2 in.) in depth and have a

minimum section modulus of 203200 cu mm/m (3.78 cu in./ft) width of grating with a maximum spacing of 50 mm (2 in.) center-to-center.

For inlet boxes for median ditch checks, steel grating shall have the main bearing bars running perpendicular to the centerline of the inlet box. The main bearing bars shall have a minimum section modulus of 132600 cu mm 3/m (2.47 cu in./ft) width of grating. The cross sectional shape shall be rectangular or a modified "I" but shall not have any flanges which would retain trash. The length and width of the grating shall be such as to leave no more than 16 mm (5/8 in.) clearance on either side when placed in the frame.

Either steel frames and grating or cast frames and grating may be used at the Contractor's option, but steel frames with cast grating or cast frames with steel grating will not be permitted.

Excavation and backfill shall be performed according to the applicable portions of Section 502. When precast units are used, a 75 mm (3 in.) deep bedding of sand conforming to Article 1003.01 for gradation FA-1 or FA-2 shall be provided under the full width and length of the unit. All voids around the pipe entrance, both inside and out, shall be sealed with mortar.

542.08 Pipe Elbows, Tees, and Collars. Pipe elbows and tees shall be installed in culvert pipe at the locations specified on the plans. The degree of elbow and the pipe size required for elbows and tees shall be detailed on the plans for each individual installation. Before the delivery of the elbows, the Contractor, with the Engineer, shall field verify the degree of elbow required for each installation.

Elbows, tees, and collars shall be of the same material as the pipe culvert.

(a) Reinforced Concrete. Reinforced concrete elbows and tees shall be fabricated according to the details shown on the plans and the following requirements.

Reinforced concrete pipe for elbows and tees shall conform to the requirements of AASHTO M 170M (M 170).

Additional reinforcement for elbows shall conform to the requirements of AASHTO M 31M (M 31) or AASHTO M 53M (M 53).

The cement mortar with bonding agent for both elbows and tees shall be approved by the Engineer prior to use.

Reinforced concrete collars shall be constructed according to Section 503 and as detailed on the plans. Reinforcement for concrete collars shall be according to Section 508.

(b) Metal. The bonding or connecting device for the elbows, tees, and/or collars will be approved by the Engineer prior to use.

542.09 Pipe Culverts (Temporary). Pipe culverts used as drainage structures for proposed temporary connections and detour roads shall be designated

Pipe Culverts (Temporary) and shall be furnished, installed and maintained by the Contractor as specified, except that the material for the pipe culvert need not be new material.

Used pipe culvert with a thickness equal to or greater than that required in Table IB or IC of Article 542.03 may be used provided it meets the approval of the Engineer. The Resident Engineer will visually inspect the pipe for acceptance. Small dents or inadequate galvanizing on the pipe will not be cause for rejection.

After the temporary connection or detour road has been removed, the pipe culvert shall become the property of the Contractor. The salvage value of the pipe shall be reflected in the unit price bid for the item of Pipe Culvert (Temporary) involved.

542.10 Method of Measurement. Pipe culverts of the diameter specified will be measured for payment in place in meters (feet) except that the length measured shall not exceed the length shown on the plans or authorized in writing by the Engineer. When elbows or tees are included in pipe culverts, the measured length of the culvert shall exclude the length of the elbow or tee section.

Additional embankment and its subsequent removal will not be measured for payment.

542.11 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for PIPE CULVERTS, or PIPE CULVERTS (TEMPORARY), of the class and type specified; or PIPE CULVERTS, SPECIAL; of the diameters or equivalent round size specified, and of the particular kind of material when specified.

The removal of unstable or unsuitable material, or rock below plan bedding grade, and the replacement with the specified material, including additional excavation required to widen the trench should such excavation be necessary to accomplish the removal of unstable or unsuitable material, or rock, will be paid for according to Article 109.04 unless the contract contains unit prices for the work included. Excavation in rock will be measured and paid for according to Section 502 for Rock Excavation for Structures.

Embankment will be measured and paid for according to Section 202 and/or Section 204.

When the Contractor has the option of using either cast-in-place reinforced concrete end sections or prefabricated end sections as specified in Article 542.07, the work will be paid for at the contract unit price each for END SECTIONS, for the size of pipe specified.

When specified on the plans, precast reinforced concrete flared end sections will be paid for at the contract unit price each for PRECAST REINFORCED CONCRETE FLARED END SECTIONS, of the diameter or equivalent round size specified.

When specified on the plans, steel end sections and aluminum end sections will be paid for at the contract unit price each for STEEL END SECTIONS and ALUMINUM END SECTIONS, respectively, of the diameter or equivalent round size specified.

End sections for polyethylene (PE) culvert pipe will be paid for at the contract unit price each for METAL END SECTIONS of the diameter specified.

When cast-in-place reinforced concrete end sections are specified on the plans, the work will be paid for at the contract unit price each for CAST-IN-PLACE REINFORCED CONCRETE END SECTIONS of the diameter specified.

When cast-in-place concrete collars are specified on the plans, the concrete will be paid for at the contract unit price per cubic meter (cubic yard) for CONCRETE COLLAR. Reinforcement will be paid for according to Section 508. Expansion bolts, when required, will be paid for according to Section 540.

When specified on the plans, elbows and tees for polyethylene or metal pipe will be paid for at the contract unit price each of PIPE ELBOW and PIPE TEE, of the diameter specified, complete in place.

Grating for precast reinforced concrete flared end sections will be paid for at the contract unit price each for GRATING FOR CONCRETE FLARED END SECTION, of the size specified.

Inlet boxes for median slopes and for side slopes will be paid for at the contract unit price each for INLET BOX, STANDARD 542501; INLET BOX, STANDARD 542521; INLET BOX, STANDARD 542511, INLET BOX, STANDARD 542506; INLET BOX, STANDARD 542536; INLET BOX, STANDARD 542516; and INLET BOX, STANDARD 542541; complete in place.

Inlet box for median ditch check will be paid for at the contract unit price each for INLET BOX, STANDARD 542526, or INLET BOX, STANDARD 542531, complete in place.

Inlet boxes to be placed flush in medians will be paid for at the contract unit price each for FLUSH INLET BOX FOR MEDIAN, STANDARD 542546, complete in place.

Reinforced concrete pipe elbows will be paid for at the contract unit price each for REINFORCED CONCRETE PIPE ELBOW, of the diameter specified, complete in place.

Reinforced concrete pipe tees will be paid for at the contract unit price each for REINFORCED CONCRETE PIPE TEE, of the pipe diameter and riser diameter specified, complete in place.

SECTION 543. INSERTION LINING OF PIPE CULVERTS

543.01 Description. This work shall consist of insertion lining of existing pipe culverts with polyethylene (PE) or reinforced plastic mortar (RPM) plastic liner pipes.

543.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Polyethylene (PE) Plastic Pipe (Note 1)	1040.16
(b) Polyethyline (PE) Profile Wall Pipe (Note 1)	1040.18
(c) Reinforced Plastic Mortar (RPM) Pipe (Note 1)	1040.17
(d) Non-Shrink Grout	1024.01
(e) Corrugated PVC with Smooth Interior (Note 1)	1040.15

Note 1. Insertion linings are specified to minimum allowable inside diameters. Any of the listed pipe materials are permitted if the inside diameter requirement is met.

Nominal	PE-F-714		RPM-D3262		Profile Wall-F894		PVC-F949	
Size mm	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
250					250	284.5	250.1	273.9
300	302.8	323.9			300	342.1	297.6	325.0
325	317.5	339.9						
350	332.5	355.6						
375					375	428.0	364.2	397.7
400	380	406.4						
450	426.7	457.2	457.2	495.3	450	514.1	445.8	486.5
500	474.2	508.0	508.0	548.6				
525					525	600.7	525.9	573.7
550	521.7	558.8						
600	569.0	609.6	609.6	655.3	600	687.3	596.1	649.7
675					675	772.9	671.6	733.0
700	664.0	711.2						
750			762.0	812.8	750	859.0	748.5	816.6
800	749.3	802.4						
900	853.7	914.4	914.4	922.8	900	1032.5	901.1	984.0
1000	936.0	1002.5			1000	1148.1		
1050	995.9	1066.8	1066.8	1130.3	1050	1205.7		
1200	1123.7	1203.5	1219.2	1290.3				
1350			1371.6	1450.3				
1375	1311.4	1404.6						
1500			1524.0	1597.7				
1600	1499.1	1605.5						
1650			1676.4	1757.7				
1800			1828.8	1915.2				
1950			1981.2	2072.6				
2100			2133.6	2235.2				
2250			2286.0	2395.2				
2400			2438.4	2555.2				

Nominal	PE-F714		RPM-D3262		Profile Wall-F894		PVC-F949	
Size in.	ID	O.D.	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
10					10	11.2	9.8	10.8
12	11.92	12.75			12	13.47	11.7	12.8
13	12.50	13.38						
14	13.09	14						
15					15	16.85	14.3	15.7
16	14.96	16						
18	16.80	18	18	19.5	18	20.24	17.6	19.2
20	18.67	20	20	21.6				
21					21	23.65	20.07	22.6
22	20.54	22						
24	22.40	24	24	25.8	24	27.06	23.5	25.6
27					27	30.43	26.4	28.9
28	26.14	28						
30			30	32.0	30	33.82	29.5	32.1
32	29.5	31.59						
36	33.61	36	36	38.3	36	40.65	35.5	38.7
40	36.85	39.47			40	45.20		
42	39.21	42	42	44.5	42	47.47		
48	44.24	47.38	48	50.8				
54			54	57.1				
55	51.63	55.3						
60			60	62.9				
63	59.02	63.21						
66			66	69.2				
72			72	75.4				
78			78	81.6				
84			84	88.0				
90			90	94.3				
96			96	100.6				

CONSTRUCTION REQUIREMENTS

543.03 General. Prior to installing the insertion lining, the culvert shall be cleared of debris or other materials so that the inserted pipe will not be resting on or against nor be irregularly supported by such materials.

Plastic Liner Pipe (PE) shall be joined into a continuous length by the butt fusion method according to ASTM D 2657 or by an approved screw-on or push-on joint. Plastic Liner Pipe (Profile Wall) shall be joined by heat fusion, extrusion, welding, screw-on, or other approved connections. Plastic Liner Pipe (RPM) or Corrugated PVC with Smooth Interior shall be joined according to the manufacturer's recommendations using joint lubricant. The joining may be accomplished in a jacking pit or other convenient location where the assembled liner can be brought into alignment with the existing culvert bore without damage. The Engineer shall approve each joint before each section of liner pipe is inserted.

The insertion may be made by pushing or pulling the assembled liner pipe from either end of the culvert. The insertion operation shall not cause the joints to separate in any way. The Engineer may require the liner to have a temporary nose cone or plug to guide the liner pipe past minor obstructions. The handling of plastic liner pipe shall be such that the pipe is not damaged. Pipe with deep scratches or gouges shall be removed and replaced by the Contractor at his/her own expense.

After the liner has been completely inserted and has been inspected in place by the Engineer, it shall be cut off flush with the ends of the existing culvert or as otherwise directed by the Engineer and grouted in place. Liner pipe that has been exposed to the sun before the insertion is made shall be allowed to cool to the temperature of the existing culvert before it is cut off and grouted. Only enough water to make a stiff but workable grout shall be used.

The grout shall extend into the annular space between the culvert and liner for a minimum distance of 150 mm (6 in.) to a flexible grout stop comprised of flexible foamed polyethylene, pavement joint backer rod, wadded newspaper or other material approved by and installed to the satisfaction of the Engineer. If the outside diameter of the liner pipe is less than 2/3 that of the inside diameter of the existing culvert, the grout shall extend for the full length of the culvert taking care that the grouting pressures are not so high as to distort the liner pipe. Where only the ends of the pipe are grouted, drainage of the annular space between the culvert and culvert liner shall be provided by drilling a circumferential line of weep holes in the lower half of the liner pipe just upstream from the downstream grout stop. The weep holes shall be not less than 10 mm (3/8 in.) nor more than 15 mm (1/2 in.) in diameter and shall be spaced circumferentially at 75 mm (3 in.) centers starting 20 degrees above the invert and extending upwards to the spring line of the liner.

543.04 Method of Measurement. Insertion culvert liners shall be measured for payment in meters (feet) in place.

543.05 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for INSERTION CULVERT LINER of the inside diameter specified.

Excavation in rock will be measured and paid for according to Section 502.

SEWERS

SECTION 550. STORM SEWERS

550.01 Description. This work shall consist of constructing storm sewers of the required inside diameter with the necessary fittings.

550.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Reinforced Concrete Arch Culvert, Storm Drain and Sewer Pipe (Note 1)	1040.07
(b)	Reinforced Concrete Culvert, Storm Drain and Sewer Pipe	1040.03
(c)	Concrete Sewer, Storm Drain and Culvert Pipe	1040.04
(d)	Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe (Note 1)	1040.05
(e)	Polyvinyl Chloride (PVC) Pipe	1040.10
(f)	Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior	1040.15
(g)	Polyvinyl Chloride (PVC) Profile Wall Pipe-794	1040.24
(h)	Extra Strength Clay Pipe	1040.02
(i)	Clay Sewer Pipe	1040.02
(j)	Performed Flexible Gaskets for Sewer and Culvert Pipe	1056
(k)	Mastic Joint Sealer for Pipe	1055
(l)	External Sealing Band	1057

Note 1. The class of elliptical and arch pipe used for various storm sewer sizes and heights of fill shall conform to the requirements for circular pipe.

550.03 Kinds of Material Permitted. The following materials will be permitted as alternates for storm sewers of the type specified. Where a particular material is specified, no other kind of material will be permitted as an alternate.

Class	Material
A	Reinforced Concrete (Article 1040.03) Reinforced Concrete Arch Culvert (Article 1040.07) Reinforced Concrete Elliptical Culvert, Storm Drain, & Sewer Pipe (Article 1040.05)
B	Reinforced Concrete (Article 1040.03) Reinforced Concrete Arch Culvert (Article 1040.07) Reinforced Concrete Elliptical Culvert, Storm Drain, & Sewer Pipe (Article 1040.05) Polyvinyl Chloride (PVC) Pipe (Article 1040.10) Corrugated Polyvinyl Chloride Pipe with a Smooth Interior (Article 1040.15) Polyvinyl Chloride (PVC) Profile Wall Pipe-794 (Article 1040.24)

When metric sizes are specified on the plans, the next larger available manufactured English pipe may be substituted at no extra cost to the Department.

The Contractor may, without additional compensation, substitute a stronger pipe of the same kind of material specified.

Extra Strength Clay Pipe, and Concrete Sewer Storm Drain and Culvert Pipe, will be permitted for storm sewer, of the types shown in the storm sewer fill height tables, for pipe Classes A and B.

For storm sewer, only a circular pipe will be permitted when storm sewer is specified to be a diameter and only reinforced concrete arch and reinforced concrete elliptical will be permitted when pipe culvert is specified as round size equivalent.

The kind of material and thickness or thickness class required for the various types of storm sewers shall be according to the following tables:

STORM SEWERS

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 1		Fill Height 1m and less with 0.3 m min. cover				Type 2		Fill Height Greater than 1 m Not Exceeding 3.0 m				Type 3		Fill Height Greater than 3.0m Not Exceeding 4.5 m			
Nom. Dia. (mm)	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794
250	NA	3	X	X	NA	N A	NA	1	*X	X	**	NA	NA	3	X	X	**	NA
300	IV			X	X	X	III	1	*X	X	X	X	IV		X	X	X	X
375	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
450	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
525	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
600	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
675	IV			X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
750	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
825	III		X	X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
900	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
1050	II	NA		NA	NA	NA	III	NA		NA	NA	NA	IV	NA		NA	NA	NA
1200	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1350	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1500	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1650	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
1800	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
1950	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2100	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2250	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2400	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2550	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2700	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA

RCCP Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP Extra Strength Clay Pipe
PVC Polyvinyl Chloride (PVC) Pipe
CPVC Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X Indicates this diameter pipe may be used.
NA Not Acceptable
* May also use standard strength Clay Sewer Pipe
** May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note RCCP Class V - 150D, etc. shall be furnished in accordance with AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

STORM SEWERS

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 1						Type 2						Type 3					
	Fill Height 3 ft and less with 1. ft min. cover						Fill Height Greater than 3 ft Not Exceeding 10 ft						Fill Height Greater than 10 ft Not Exceeding 15 ft					
Nom. Dia. (in.)	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794
10	NA	3	X	X	NA	N A	NA	1	*X	X	**	NA	NA	3	X	X	**	NA
12	IV			X	X	X	III	1	*X	X	X	X	IV		X	X	X	X
15	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
18	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
21	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
24	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
27	IV			X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
30	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
33	III		X	X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
36	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
42	II	NA		NA	NA	NA	III	NA		NA	NA	NA	IV	NA		NA	NA	NA
48	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
54	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
60	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
66	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
72	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
78	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
84	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
90	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
96	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
102	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
108	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA

RCCP Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP Extra Strength Clay Pipe
PVC Polyvinyl Chloride (PVC) Pipe
CPVC Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X Indicates this diameter pipe may be used.
NA Not Acceptable
* May also use standard strength Clay Sewer Pipe
** May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note RCCP Class V - 3160D, etc. shall be furnished in accordance with AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

STORM SEWERS

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 4 Fill Height Greater than 4.5 m Not exceeding 6.0 m				Type 5 Fill Height Greater than 6.0 m Not Exceeding 7.5 m				Type 6 Fill Height Greater than 7.5 m Not Exceeding 9.0 m			
Nom. Dia. (mm)	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794
250	NA	X	**	N A	NA	X	**	NA	NA	X	**	NA
300	V	X	X	X	V-150D	X	X	X	V-180D	X	X	X
375	V	X	X	X	V-145D	X	X	X	V-160D	X		
450	V	X	X	X	V	X	X	X	V-150D	X		
525	V	X	X	X	V	X	X	X	V	X		
600	V	X	X	X	V	X	X	X	V	X		
675	V	X	NA	NA	V	X	NA	NA	V	X	NA	NA
750	V	X	X	X	V	X			V	X		
825	IV	X	NA	NA	V	X	NA	NA	V	X	NA	NA
900	IV	X	X	X	V	X			V	X		
1050	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1200	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1350	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1500	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1650	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
1800	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
1950	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2100	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2250	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2400	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2550	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2700	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 150D, etc. shall be furnished in accordance with AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 4 Fill Height Greater than 15 ft Not exceeding 20 ft				Type 5 Fill Height Greater than 20 ft Not Exceeding 25 ft				Type 6 Fill Height Greater than 25 ft Not Exceeding 30 ft			
Nom. Dia. (in.)	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794
10	NA	X	**	N A	NA	X	**	NA	NA	X	**	NA
12	V	X	X	X	V-3160D	X	X	X	V-3790D	X	X	X
15	V	X	X	X	V-3080D	X	X	X	V-3390D	X		
18	V	X	X	X	V	X	X	X	V-3115D	X		
21	V	X	X	X	V	X	X	X	V	X		
24	V	X	X	X	V	X	X	X	V	X		
27	V	X	NA	NA	V	X	NA	NA	V	X	NA	NA
30	V	X	X	X	V	X			V	X		
33	IV	X	NA	NA	V	X	NA	NA	V	X	NA	NA
36	IV	X	X	X	V	X			V	X		
42	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
48	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
54	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
60	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
66	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
72	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
78	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
84	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
90	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
96	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
102	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
108	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
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PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 3160D, etc. shall be furnished in accordance with AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

STORM SEWERS

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE
RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 7	Fill Height Greater than 9.0 m Not exceeding 10.5 m
Nom. Dia. (mm)	RCCP Class	PVC
250	NA	X
300	V-190D	X
375	V-170D	X
450	V-160D	X
525	V-150D	X
600	V	X
675	V	X
750	V	X
825	V	X
900	V	X
1050	V	NA
1200	V	NA
1350	V	NA
1500	V	NA
1650	V	NA
1800	V	NA
1950	V	NA
2100	V	NA
2250	V	NA
2400	V	NA
2550	V	NA
2700	V	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 150D, etc. shall be furnished in accordance with AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE
RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

	Type 7	Fill Height Greater than 30 ft Not exceeding 35 ft
Nom. Dia. (in.)	RCCP Class	PVC
10	NA	X
12	V-4000D	X
15	V-3575D	X
18	V-3300D	X
21	V-3110D	X
24	V	X
27	V	X
30	V	X
33	V	X
36	V	X
42	V	NA
48	V	NA
54	V	NA
60	V	NA
66	V	NA
72	V	NA
78	V	NA
84	V	NA
90	V	NA
96	V	NA
102	V	NA
108	V	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 3160D, etc. shall be furnished in accordance with AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

CONSTRUCTION REQUIREMENTS

550.04 Excavation and Foundation. The trench shall be excavated to an elevation 100 mm (4 in.) below the bottom of the pipe and so that the flow line of the finished sewer will be at the depth or grade specified or established by the Engineer. For trench depths of less than 1.5 m (5 ft) and when sheeting or shoring is not required, the trench shall be excavated 450 mm (18 in.) wider than the external diameter of the pipe to permit thorough tamping of the foundation material under the haunches and around the pipe. For trench depths of 1.5 m (5 ft) or more and when sheeting or shoring is required, the trench width shall be 1 m (3 ft) wider than the external diameter of the pipe. The trench shall be excavated so that vertical faces are maintained at least to the elevation of the top of pipe. For trench depths of 1.5 m (5 ft) or more, the Contractor shall provide trench protection according to the applicable standards for work place safety. The Contractor shall provide to the Engineer, in writing, his/her procedures for fulfilling the safety requirements for trench protection.

If a water main is encountered during storm sewer construction, the requirements of the IEPA shall govern the horizontal and vertical separation of the water main from the storm sewer.

Well compacted, moist fine aggregate meeting the gradations specified in Article 1003.04 to at least 100 mm (4 in.) in depth below the pipe, shall be placed the entire width of the trench and for the length of the pipe. The fine aggregate shall meet the approval of the Engineer and shall be compacted to the Engineer's satisfaction by ramming or tamping with tools approved by the Engineer. When the storm sewer outlets from an embankment or natural ground, the last 1 m (3 ft) of the bedding and backfill at the outfall end shall be impervious material.

When pipe having bells or hubs is used, cross trenches, not more than 50 mm (2 in.) wider than the bell or hub, shall be excavated to provide uniform bearing along the length of the pipe.

If the excavation has been made deeper than necessary, the foundation shall be brought to the proper grade by the addition of well compacted bedding material.

Where a firm foundation is not encountered at the grade established due to soft, spongy or other unsuitable soil, unless other special construction methods are called for in the contract, all such unsuitable soil under the pipe and for the width of the trench shall be removed and replaced with well-compacted bedding material.

Where rock, in either ledge or boulder formation, is encountered, it shall be removed to an elevation at least 200 mm (8 in.) below the bottom of the pipe and replaced with a cushion of well compacted bedding material.

All excavated material not needed on the work shall be disposed of according to Article 202.03.

550.05 Plugging Existing Sewers and Drains. Abandoned sewers and drains, as designated by the Engineer, shall be plugged with Class SI Concrete or brick and suitable mortar to the satisfaction of the Engineer.

This work will not be paid for separately, but shall be considered as included in the contract unit price bid for the Storm Sewer items or in the absence of such items for Earth Excavation.

550.06 Laying Sewer Pipe. The Contractor shall, at his/her own expense, keep the trench free from water while the sewer is being placed and until the joint has been sealed. The laying of pipes in finished trenches shall be started at the outlet end with the spigot ends pointing in the direction of flow, and shall proceed toward the inlet end with pipes abutting and true to line and grade. The flow line at the outlet end of the pipe shall be not less than 150 mm (6 in.) above the flow line of the open ditch at the outlet.

The ends of pipes shall be carefully cleaned before the pipes are lowered into the trenches, and the pipes shall be lowered so as to avoid unnecessary handling in the trench.

As each length of pipe is laid, the mouth of the pipe shall be properly protected to prevent the entrance of earth or the bedding material. The pipes shall be fitted and matched so that when laid in the work they will form a sewer with a smooth, uniform invert. If reinforced concrete pipe is used, the word "Top" or "Bottom" may be stenciled on the inside of the pipe sections. All concrete pipe so marked shall be placed as indicated by these marks.

All joints in concrete sewer pipe shall be sealed with preformed flexible gasket or mastic joint sealer conforming to Sections 1056 or 1055 or external sealing bands conforming to Section 1057. When mastic joint sealer is used, the material shall completely fill the joint after the pipes have been brought together. PVC pipe shall be joined according to ASTM D 3034. The mastic joint sealer shall be used according to the recommendations of the manufacturer. After each joint is sealed, it shall be wiped clean on the inside. Lifting holes shall be filled with a precast concrete plug sealed and covered with mastic or mortar. Each section of pipe shall be pushed or pulled to the section in place to ensure tight joints. Pipe having a diameter greater than 1 m (42 in.) shall be set or "brought home" with a winch, come-a-long or other positive means.

550.07 Backfilling. As soon as the condition of the pipe will permit, the entire width of the trench shall be backfilled with moist fine aggregate meeting the gradations specified in Article 1003.04 to a height of at least the elevation of the center of the pipe. The fine aggregate shall be placed longitudinally along the pipe. The elevation of the backfill material on each side of the pipe shall be the same. Special care shall be taken to completely fill the space under the pipe. The fine aggregate backfill material shall be placed in 200 mm (8 in.) layers, loose measurement and compacted to the satisfaction of the Engineer by ramming or tamping with tools approved by the Engineer. The fine aggregate used for backfilling shall meet the approval of the Engineer.

The remainder of the trench and excavation shall be backfilled to the natural line or finished surface as rapidly as the condition of the sewer will permit. The backfill

material shall consist of the excavated material or of trench backfill, as herein specified. All backfill material shall be deposited in the trench or excavation in such a manner as not to damage the sewer. The filling of the trench shall be carried on simultaneously on both sides of the pipe in such a manner that injurious side pressures do not occur. The backfill for trenches and excavation made in the subgrade of the proposed improvement, and for all trenches outside of the subgrade where the inner edge of the trench is within 600 mm (2 ft) of the edge of the proposed pavement, curb, gutter, curb and gutter, stabilized shoulder or sidewalk, shall be made with trench backfill material, unless the excavated material meets the requirements of Articles 1003.01 and 1003.04.

All backfill material up to a height of 300 mm (12 in.) above the pipe shall be carefully deposited in uniform layers not exceeding 200 mm (8 in.) thick (loose measure). The material in each layer shall be firmly compacted by ramming or tamping with tools approved by the Engineer in such a manner as not to disturb or damage the pipe. The backfilling above this height shall be done by Method 1, 2 or 3 below.

When required, trench backfill material or excavated material meeting the requirements of Articles 1003.01 and 1003.04 above the first 300 mm (12 in.) above the pipe, shall be compacted by either Method 2 or Method 3 specified below, or according to Method 1, except that the compacted lifts shall not exceed 200 mm (8 in.) in thickness.

Method 1. The material shall be deposited in uniform layers not exceeding 300 mm (12 in.) thick (loose measure), and each layer shall be compacted by ramming or tamping with tools approved by the Engineer.

Method 2. The material shall be deposited in uniform layers not exceeding 300 mm (12 in.) thick (loose measure), and each layer shall be either inundated or deposited in water.

Method 3. The trench shall be backfilled with loose material, and settlement secured by introducing water through holes jetted into the backfill to a point approximately 600 mm (2 ft) above the top of the pipe. The holes shall be spaced as directed by the Engineer but shall be no farther than 2 m (6 ft) apart.

The water shall be injected at a pressure just sufficient to sink the holes at a moderate rate of speed. The pressure shall be such that the water will not cut cavities in the backfill material nor overflow the surface. If water does overflow the surface, it shall be drained into the jetted holes by means of shallow trenches.

Water shall be injected as long as it will be absorbed by the backfill material and until samples taken from test holes in the trench show a satisfactory moisture content. The Contractor shall bore the test holes not more than 15 m (50 ft) apart and at such other locations in the trench designated by the Engineer. As soon as the water soaking has been completed, all holes shall be filled with soil and compacted by ramming with a tool approved by the Engineer.

Backfill material which has been water soaked shall be allowed to settle and dry for at least 10 days before any surface course or pavement is constructed on it. The length of time may be altered, if deemed desirable, by the Engineer. Where the inner

edge of the trench is within 600 mm (2 ft) of the edge of the proposed pavement, curb, gutter, curb and gutter, stabilized shoulder or sidewalk, the provisions of this paragraph shall also apply.

At the end of the settling and drying period, the crusted top of the backfill material shall be scarified and, if necessary, sufficient backfill material added, as specified in Method 1, to complete the backfilling operations.

The method used for backfilling and compacting the backfill material shall be the choice of the Contractor. If the method used does not produce results satisfactory to the Engineer, the Contractor will be required to alter or change the method being used so that the resultant backfill will be satisfactory to the Engineer. Should the Contractor be required to alter or change the method being used, no additional compensation will be allowed for altering or changing the method.

When sheeting and bracing have been used, sufficient bracing shall be left across the trench as the backfilling progresses to hold the sides firmly in place without caving or settlement. This bracing shall be removed as soon as practicable. Any depressions which may develop within the area involved in the construction operation due to settlement of the backfilling material shall be filled in a manner meeting the approval of the Engineer.

When the Contractor constructs the trench with sloped sides or benched according to the requirements of Article 550.04, backfilling for the full width of the excavation shall be as hereinbefore specified, except no additional compensation will be allowed for trench backfill material required outside the vertical limits of the specified trench width.

Whenever excavation is made for installing sewer pipe across earth shoulders or private property, the topsoil disturbed by excavation operations shall be replaced as nearly as possible in its original position, and the whole area involved in the construction operations shall be left in a neat and presentable condition.

When using any PVC pipe the pipe shall be backfilled with a moist fine aggregate to 300 mm (1 ft) over the top of the pipe and compacted to a minimum of 85 percent of standard lab density.

When reinforced concrete pipes are used, the backfill shall be compacted to a minimum of 85 percent of standard lab density when the trench is within 600 mm (2 ft) of the pavement structure.

Deflection Testing for Storm Sewers. All PVC storm sewers will be tested for deflection not less than 30 days after the pipe is installed and the backfill compacted.

For PVC storm sewers with diameters 600 mm (24 in.) or smaller, a mandrel drag shall be used for deflection testing. For PVC storm sewers with diameters over 600 mm (24 in.), deflection measurements other than by a mandrel drag shall be used.

Where the mandrel is used, the mandrel shall be furnished by the Contractor and pulled by hand through the pipeline with a suitable rope or cable connected to each end. Winching or other means of forcing the deflection gauge through the pipeline will not be allowed.

The mandrel shall be of a shape similar to that of a true circle enabling the gauge to pass through a satisfactory pipeline with little or no resistance. The mandrel shall be of a design to prevent it from tipping from side to side and to prevent debris build-up from occurring between the channels of the adjacent fins or legs during operation. Each end of the core of the mandrel shall have fasteners to which the pulling cables can be attached. The mandrel shall have nine, various sized fins or legs of appropriate dimension for various diameter pipes. Each fin or leg shall have a permanent marking that states its designated pipe size and percent of deflection allowable.

The outside diameter of the mandrel shall be 95 percent of the base inside diameter, where the base inside diameter is:

For all PVC pipe: as defined using ASTM D 3034 methodology.

If the pipe is found to have a deflection greater than that specified, that pipe section shall be removed, replaced, and retested.

550.08 Method of Measurement. Storm sewers of the different types and diameters will be measured for payment in place in meters (feet).

When the storm sewer enters a manhole, inlet or catch basin, the measurement will end at the inside wall of the manhole, inlet or catch basin. Allowance will be made for the length of pipe necessary to permit the pipe to meet the sides of the manhole. No payment for storm sewer will be made through an inlet or manhole where the inlet or manhole is paid for as a separate item. However, when the storm sewer is continuous and the inlet is constructed on top of the storm sewer, the measurement will be from end to end of storm sewer with a deduction made for the tee section which is paid for separately. Measurement of the pipe will not be made by counting lengths of pipe or joints.

Trench backfill will be measured for payment as specified in Article 208.03.

Excavation in rock will be measured for payment as specified in Article 502.14.

550.09 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for STORM SEWERS, of the class, type, and diameter specified, and of the kind of material when specified.

Trench backfill will be paid for according to Article 208.04.

Excavation in rock will be classified and paid for according to Article 502.15 for Rock Excavation for Structures.

Removal and replacement of unsuitable material below plan bedding grade will be paid for according to Article 109.04.

SECTION 551. STORM SEWER REMOVAL AND INSTALLATION

551.01 Description. This work shall consist of the removal and or installation of storm sewers, including laterals.

CONSTRUCTION REQUIREMENTS

551.02 Removal. Existing storm sewers shall be removed so that all pipe considered suitable by the Engineer for future use shall be salvaged. The location and manner of storage of salvaged material shall be as directed by the Engineer. Any of the material having salvage value which has been damaged by the Contractor shall be replaced by the Contractor, at his/her own expense, with new pipe of the same kind and size. Material not suitable for salvage shall be disposed of by the Contractor according to Article 202.03.

Trenches resulting from the removal of storm sewers shall be backfilled according to the applicable requirements of Article 550.07.

551.03 Installation. Suitable pipe salvaged from storm sewer removal shall be used when available. All new materials shall meet the requirements of Articles 550.02 and 550.03.

When salvaged pipe is available for use, any new material required shall be of the same kind as the salvaged pipe.

Storm sewer installation shall be performed according to the applicable requirements of Section 550. The Contractor, at his/her own expense, shall replace pipe damaged by the Contractor with pipe of the same kind and size.

551.04 Method of Measurement. Storm sewer removal of the various diameters will be measured for payment in meters (feet), measured as removed.

Storm sewer installation of the different diameters will be measured for payment in place in meters (feet) according to the applicable requirements of Article 550.08.

Excavation in rock will be measured for payment as specified in Article 502.14.

Trench backfill will be measured for payment as specified in Article 208.03.

551.05 Basis of Payment. Storm sewer removal will be paid for at the contract unit price per meter (foot) for STORM SEWER REMOVAL, of the diameter specified, which price shall include all excavation and backfilling, and removing and salvaging the pipe.

Storm sewer installation will be paid for at the contract unit price per meter (foot) for STORM SEWER INSTALLATION, of the diameter specified, which price shall include all materials except furnishing new pipe and trench backfill, all excavation except excavation in rock and excavation to remove unsuitable material below plan bedding grade, backfilling, and all sheeting or shoring required.

The furnishing of all new pipe, except for replacement of pipe damaged by the Contractor, will be paid for according to Article 109.04.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

Trench backfill will be paid for as specified in Article 208.04.

Removal and replacement of unsuitable material below plan bedding grade will be paid for according to Article 109.04.

SECTION 552. STORM SEWERS JACKED IN PLACE

552.01 Description. This work shall consist of furnishing and installing, by jacking, storm sewers of the required inside diameter at locations shown on the plans.

552.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Reinforced Concrete Culvert, Storm Drain and Sewer Pipe (Note 1)	1040.03
(b) Reinforced Concrete Elliptical Culverts, Storm Drain and Sewer Pipe (Note 1)	1040.05

Note 1. Tongue and Groove Type Joint. Not less than a Class IV Pipe.

552.03 Traffic Control. The road shall be kept open to to traffic according to Article 701.05(d)(3).

CONSTRUCTION REQUIREMENTS

552.04 General. Storm sewers, of the type and size specified, shall be jacked in a continuous operation. The construction may be accomplished by jacking the storm sewer, or if the Contractor elects, a metal liner of sufficient strength and size first, then the storm sewer installed inside the liner. If the liner is used, it shall remain in place to support the embankment, and the voids between the liner and the sewer pipe shall be completely filled with sand or grout mixture as approved by the Engineer. The diameter of the metal liner, if used, shall not exceed the outside diameter of the storm sewer by more than 150 mm (6 in.).

The Contractor may shorten the length of storm sewer to be jacked by open cutting and sheeting, shoring or bracing the excavation outside the roadway limits. No open cutting shall be permitted inside the shoulder lines. If continuous jacking operation cannot be maintained, the Contractor shall take the necessary precautions for not allowing the jacked pipe to freeze in place.

All sheeting, bracing, shoring, jacking frame, guide rails, backstop, shields, sleeves and other materials necessary for the complete installation of the storm

sewer shall be of sufficient strength to support the loads that are to be imposed on them.

The types, sizes and number of jacks, jacking pit and other equipment used shall be such as to exert sufficient force to overcome the greatest resistance to be encountered, considering both weight of the pipe or liner and the friction on its exterior surface. Lubricants, if required, may be used to decrease the frictional resistance on the exterior surface of the pipe being jacked. Suitable lubricants may be applied directly to the surface or through 13 mm (1/2 in.) nipples through holes drilled in the cutting shield at the lead pipe.

Care shall be taken in arranging the jacking equipment and struts to ensure that thrust is applied parallel with the centerline of the pipe or liner or as approved by the Engineer. A jacking head or collar shall be used to apply pressure from the jack to the pipe or liner. Pressure applied with the metal of the jack in direct contact with concrete pipe will not be permitted.

A cutting edge at least 13 mm (1/2 in.) greater in diameter than the pipe or liner being jacked shall be provided for the leading pipe or liner. The upper half of the cutting edge shall project beyond the pipe or liner end to support the embankment. Excavation within the jacked pipe or liner shall be performed in such a manner as to not increase the excavated diameter larger than the pipe or liner being jacked. Excavation shall not be carried beyond the end of the cutting edge of the pipe or liner. Any holes provided in the lead pipe to attach the cutting edge shall be properly filled with plug and mastic as approved by the Engineer after completion of the jacking operation and removal of cutting edge.

552.05 Joints. As each succeeding pipe section is placed against the previously jacked pipe, a 13 mm (1/2 in.) manila rope or other suitable material shall be inserted throughout the entire groove of the joint and set in place with asphalt mastic. The opening on the inside of the pipe shall be mortared with a mixture composed of one part cement to three parts sand, by volume, based on dry materials, after the complete sewer has been jacked in place. Any other method of jointing must be approved by the Engineer prior to the start of construction.

552.06 Accuracy of Placement. The alignment and elevation of the forward end of the pipe shall be checked at regular intervals as work proceeds and appropriate measures immediately taken to correct any observed deviation. When the Contractor elects to jack a metal liner prior to installing the storm sewer, all earth and other foreign material shall be removed from inside the liner. The storm sewer sections shall be installed by jacking the sections through the liner.

552.07 Method of Measurement. Storm sewers jacked in place of the different diameters will be measured for payment in meters (feet) in place.

Excavation in rock will be measured for payment as specified in Article 502.14.

552.08 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for STORM SEWERS JACKED IN PLACE, of the diameter specified, which price shall include the storm sewer, metal liner if used, including backfilling all voids between the storm sewer and metal liner, all other materials and equipment necessary to install the storm sewer and all excavation except excavation in rock.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

UTILITIES

SECTION 560. CAST IRON SOIL PIPE

560.01 Description. This work shall consist of constructing cast iron soil pipe of the required inside diameter.

560.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Cast Iron Soil Pipe	1006.20

CONSTRUCTION REQUIREMENTS

560.03 General. Construction requirements shall conform to Section 550 with the following exceptions:

The pipe shall be laid with its spigot end lacking 5 mm (1/4 in.) of being driven full into the bell. Gaskets of clean, sound hemp yarn braided or twisted and tightly driven shall be used to pack the joints, followed by caulking with pure soft lead of the best quality for the purpose, so as to make a tight and permanent joint. All pipes shall be carefully cleaned before laying, and shall be left clean and in working order. The pipe shall have a solid bearing throughout its entire length. If it becomes necessary to cut the pipe, it shall be cut in such a manner that the ends will be square with the axis of the pipe.

560.04 Method of Measurement. Cast iron soil pipe of the various diameters will be measured for payment in meters (feet), measured in place.

Excavation in rock will be measured for payment as specified in Article 502.14.

Trench backfill will be measured for payment as specified in Article 208.03.

560.05 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for CAST IRON SOIL PIPE, of the diameter specified, which price shall include all pipe fittings, joint materials and all excavation, except excavation in rock.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

Trench Backfill will be paid for as specified in Article 208.04.

SECTION 561. WATER MAIN

561.01 Description. This work shall consist of constructing water main of the required material and inside diameter.

561.02 Materials. Materials shall be as shown in the contract.

CONSTRUCTION REQUIREMENTS

561.03 General. Installation methods shall conform to the manufacturer's recommendations for the type of pipe being installed with the following exceptions:

(a) Excavation and Foundation. The applicable requirements of Article 550.04 shall govern the performance of this work.

(b) Requirements for the Protection of Water Mains from Sewers. The requirements of the IEPA shall govern the horizontal and vertical separation of water mains from sewers.

(c) Backfilling. The applicable requirements of Article 550.07 shall govern the performance of this work except that backfilling shall not be done in freezing weather without written permission of the Engineer, and it shall not be made with frozen material. No backfill shall be made where the material already in the trench is frozen.

Backfilling around joints shall not be made until the hydrostatic tests have been made and any leaks have been repaired.

561.04 Hydrostatic Tests. Hydrostatic tests will be performed according to Section 13 of the American Water Works Association Specifications, Designation: AWWA C600. The water main will be subjected to the hydrostatic pressure and leakage tests specified in the Special Provisions. Water for making the hydrostatic and leakage tests shall be furnished by the Contractor at his/her own expense and shall be of satisfactory bacteriological quality for drinking purposes.

561.05 Disinfection of Water Main. Upon completion of the newly laid water main, the water main shall be disinfected according to the American Water Works Association, Procedure Designation: AWWA C651.

561.06 Method of Measurement. Water main of the various diameters will be measured for payment in meters (feet), measured in place.

Excavation in rock will be measured for payment as specified in Article 502.14.

Trench backfill will be measured for payment as specified in Article 208.03.

561.07 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for WATER MAIN, of the diameter specified, which price shall include all pipe fittings, joint materials, the hydrostatic tests, disinfecting of the water main and all excavation, except excavation in rock.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

Trench Backfill will be paid for as specified in Article 208.04.

SECTION 562. WATER SERVICE LINE

562.01 Description. This work shall consist of constructing water service line of the required material and inside diameter.

562.02 Materials. All materials shall be as shown on the plans or as included in the Special Provisions.

CONSTRUCTION REQUIREMENTS

562.03 General. Any excavation required shall be only sufficient to install the water service line.

Installation of the water service line shall be made in a manner meeting the approval of the Engineer.

The requirements of the IEPA shall govern the horizontal and vertical separation of water service lines from sewers.

The applicable requirements of Article 550.07 shall govern the backfilling, except that backfilling shall not be done in freezing weather without permission of the Engineer, and it shall not be made with frozen material. No backfill shall be made where the material already in the trench is frozen.

562.04 Method of Measurement. Water service line of the various diameters will be measured for payment in meters (feet), measured in place.

Excavation in rock will be measured for payment as specified in Article 502.14.

Trench backfill will be measured for payment as specified in Article 208.03.

562.05 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for WATER SERVICE LINE, of the internal diameter specified, which price shall include all pipe fittings, joint materials and all excavation, except excavation in rock.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

Trench Backfill will be paid for as specified in Article 208.04.

SECTION 563. ADJUSTING SANITARY SEWERS AND WATER SERVICE LINES

563.01 Description. This work shall consist of adjusting sanitary sewers and water service lines, where required by the construction of the improvement.

563.02 Materials. Materials shall be as shown on the plans or as included in the Special Provisions. Materials for replacement shall be the same kind as, or equal to, the material being replaced.

CONSTRUCTION REQUIREMENTS

563.03 General. When the contract includes information concerning the number, locations, and lengths of sanitary sewers and water service lines which are to be adjusted, such information represents the best knowledge of the Department and is included for the convenience of the bidder. The Department assumes no responsibility whatever in respect to the sufficiency or accuracy of the information shown. It shall be the Contractor's responsibility to determine the exact locations of all such installations. The Contractor shall also obtain from the governmental agency or utility company responsible for the respective installations, detailed information concerning the locations of the installations. The work shall conform to the Standard Specifications for Water and Sewer Main Construction in Illinois. No additional compensation will be allowed the Contractor due to any delays or inconvenience resulting from these requirements, nor on account of any special construction methods required in prosecuting the Contractor's work.

When a Sanitary District, Municipality or Water District has jurisdiction of a sanitary sewer or water service line, the work shall be performed as prescribed by the Sanitary District, Municipality or Water District and shall meet the approval of its Engineer.

If the Contractor damages any sanitary sewer or water service line not requiring adjustment, or any other underground structure or utility, the Contractor shall replace or repair it as required by the Engineer, and no additional compensation will be allowed.

When a sanitary sewer or water service line is to be adjusted, the Contractor shall remove it carefully to prevent damage to the pipe. Any material, including fittings, which is not satisfactory for reuse, in the opinion of the Engineer, shall be replaced and payment will be made for the replacement material according to Article 109.04. Any material, including fittings, which is damaged by the Contractor due to his/her negligence, shall be replaced by the Contractor at his/her own expense.

All material removed and not reused shall become the property of the Contractor. The salvage value of this material shall be reflected in unit price bid for the items involved.

563.04 Adjusting Sanitary Sewers. The work necessary to adjust sanitary sewers shall be performed according to the applicable requirements of Section 550.

563.05 Adjusting Water Service Lines. The work necessary to adjust water service lines shall be performed according to the applicable portions of Section 562.

Any water service line, other than copper, which is or will be under a base or surface course and which requires adjustment, shall be replaced with copper pipe conforming to the requirements of Article 1006.33.

563.06 Method of Measurement. Adjusting sanitary sewers and water service lines will be measured for payment in meters (feet) complete in place. The length of sanitary sewers, 200 mm (8 in.) in diameter or less, and those over 200 mm (8 in.), shall be measured separately.

Excavation in rock will be measured for payment as specified in Article 502.14.

Trench backfill will be measured for payment as specified in Article 208.03.

563.07 Basis of Payment. This work will be paid for at the contract unit prices per meter (foot) for ADJUSTING SANITARY SEWERS, (200 MM (8 IN. DIAMETER OR LESS), ADJUSTING SANITARY SEWERS, (OVER 200 MM (8 IN.) DIAMETER) and ADJUSTING WATER SERVICE LINES; which prices shall include all joint materials, making all connections, excavation except excavation in rock, and backfilling.

Excavation in rock will be paid for as specified in Article 502.15 for Rock Excavation for Structures.

Trench Backfill will be paid for as specified in Article 208.04.

The furnishing of materials required to replace material declared unsatisfactory by the Engineer and new materials necessary to complete the work, except as above noted, will be paid for according to Article 109.04.

SECTION 564. MOVING FIRE HYDRANTS

564.01 Description. All existing fire hydrants which interfere with the construction of the proposed improvement shall be relocated or adjusted as indicated on the plans or required by the Engineer. This item includes fire hydrants with auxiliary valves and the adjustment of the fire hydrants and the auxiliary valves to the new elevations required by the proposed improvement.

CONSTRUCTION REQUIREMENTS

564.02 General. Fire Hydrants shall be set on a firm foundation and shall be thrust blocked according to the details shown on the plans and as directed by the Engineer.

Thrust blocking shall consist of Class SI Concrete cast against the fittings and the undisturbed earth on the side where the thrust is expected to occur. A minimum of 0.2 m^3 (1/4 cu. yd.) of concrete shall be used for the thrust block. The dimensions of the thrust block shall be determined by the Engineer. Blocking shall be placed such that the pipe, fittings and joints shall be accessible for future repair.

Upon completion of relocating or adjusting the fire hydrant, it shall be tested and disinfected as specified in Articles 561.04 and 561.05.

The hole formed by the removal of a fire hydrant and the remaining excavated area around the relocated fire hydrant shall be backfilled with fine aggregate.

Any fire hydrant damaged by the Contractor shall be repaired at his/her own expense.

The work shall be performed in a manner approved by the Engineer of the municipality or the Water District.

564.03 Basis of Payment. This work will be paid for at the contract unit price each for FIRE HYDRANTS TO BE MOVED. When fire hydrants are not located or relocated as shown on the plans or when hydrants not shown on the plans are to be moved, the work will be paid for according to Article 109.04.

SECTION 565. MOVING DOMESTIC METER VAULTS AND WATER SERVICE BOXES

565.01 Description. All domestic meter vaults and water service boxes which are to be moved shall be removed and reset back of the proposed curb, or as directed by the Engineer.

The hole formed by the removal of the domestic meter vault or water service box shall be backfilled with fine aggregate.

Any domestic meter vault or water service box, including the stop cocks, which are damaged by the Contractor shall be repaired at his/her own expense.

The work shall be performed in a manner approved by the Engineer of the municipality, or the Water District.

565.02 Basis of Payment. This work will be paid for at the contract unit price each for DOMESTIC METER VAULTS TO BE MOVED or DOMESTIC WATER SERVICE BOXES TO BE MOVED, which price shall be payment in full for all excavation; furnishing all materials, except any necessary pipe; wiping joints; backfilling, including fine aggregate; and disposal of surplus materials.

MISCELLANEOUS

SECTION 580. MEMBRANE WATERPROOFING FOR RAILWAY STRUCTURES

580.01 Description. This work shall consist of furnishing, transporting and placing all materials required to construct a membrane waterproofing system on railway structures.

The membrane waterproofing shall be of the bituminous or butyl rubber type as specified on the plans.

580.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Waterproofing Materials (Note 1)	1060
(b)	Fine Aggregate	1003.05

Note 1. The bitumen used shall be asphalt. The bitumen for mopping and for the protective cover shall be the same type as that with which the fabric is treated.'

CONSTRUCTION REQUIREMENTS

580.03 General. Surfaces to be waterproofed shall be smooth and free from projections which might damage the waterproofing membrane and there shall be no depressions in horizontal surfaces of the finished waterproofing. Projections or depressions on the surface on which the membrane is to be applied that may cause injury to the membrane shall be removed or filled as directed by the Engineer. The surface shall be cleaned of dust, dirt, grease and loose particles, and shall be dry before the waterproofing is applied. Concrete surfaces shall not be waterproofed until a period of at least seven days has elapsed after the placing of the concrete, unless otherwise approved by the Engineer.

There shall be no depressions or pockets in horizontal surfaces of the finished waterproofing. The membrane shall be carefully turned into drainage fittings. Special care shall be taken to make the waterproofing effective along the sides and ends of girders and at stiffeners, gussets and all other plates where the membrane terminates.

Bituminous membrane waterproofing shall not be applied when the atmospheric temperature is below 10 ºC (50 ºF) and butyl rubber membrane shall not be applied when the atmospheric temperature is below -12 ºC (10 ºF), without written permission of the Engineer.

Surfaces of concrete or steel that are to be waterproofed shall be given one coat of Asphalt Primer: RC-70, before the first mopping of Asphalt: AWP, except that at construction and expansion joints where insulation is to be used, the surfaces shall not be coated with primer. The primer shall be applied to the surface in a uniform coating and may be applied without heating. A minimum of 4 L (1 gal.) of primer per 10 sq m 100 sq. ft) of surface shall be used. The priming coat shall be applied at least 24 hours before applying the waterproofing membrane and it shall be dry before the first mopping of bitumen is applied.

The primer shall be omitted for a width of 225 mm (9 in.) on each side of construction and expansion joints and a strip of insulating paper 450 mm (18 in.) wide shall be laid thereon before the waterproofing is applied. Insulating paper shall be a waterproof paper weighing not less than 0.5 kg/sq m (10 lb/100 sq ft).

Expansion joints and grooves shall be dry and clean and, shall be filled with plastic cement. Expansion joints and grooves filled with plastic cement shall be overfilled to allow for shrinkage.

580.04 Membrane Application. Bituminous and butyl rubber membranes shall be applied as specified.

(a) Bituminous Membrane. On surfaces that are vertical, or nearly so, the strips of fabric shall be laid vertically or with the slope; on other surfaces the strips shall be laid horizontally, beginning at the lowest part of the surface to be waterproofed. Sufficient fabric shall be allowed for anchorage at the upper edge of the surface to be waterproofed.

Surfaces to be waterproofed shall be mopped in sections. While the first mopping of bitumen is still hot, a strip of fabric shall be laid on the mopping and pressed into place. Each mopping thereafter shall be applied so that it will completely cover and seal the fabric. The amount of bitumen used for each mopping shall be not less than 1.8 L/sq m (4 1/2 gal. per 100 sq. ft) of surface. The bitumen for mopping shall be heated to a temperature which will permit uniform application. Asphalt shall not be heated above a temperature of 175 ºC (350 ºF).

Asphalt: AWP shall be used for mopping asphalt saturated cotton fabric.

Application of bituminous membrane shall be started by mopping a section of the surface 50 mm (2 in.) wider than 1/3 of the width of fabric. On this hot mopping, a 1/3 width of fabric shall be laid. The top surface of this fabric and an adjacent section of the surface 50 mm (2 in.) wider than 1/3 width of fabric shall then be mopped. On this hot mopping, a 2/3 width of fabric shall be laid completely covering the first strip. The top surface of this fabric and an adjacent section of the surface 50 mm (2 in.) wider than 1/3 width of fabric shall then be mopped. On this hot mopping shall be laid a full width of fabric completely covering the first and second strips. The top surface of this fabric and adjacent section, the width of 1/3 width of the fabric, shall then be mopped. On this hot mopping, the second full strip of fabric shall be laid lapping the first 1/3 width of the fabric at least 50 mm (2 in.). Thereafter, full widths of fabric shall be laid in hot moppings of bitumen and in such manner that each strip will lap the third preceding strip at least 50 mm (2 in.). Side laps shall be not less than 50 mm (2 in.) and end laps not less than 300 mm (12 in.).

The bituminous membrane shall be free from punctures, pockets or folds, and patching shall not be done without the permission of the Engineer. Where patching is permitted for defective waterproofing, the first ply shall extend at least 300 mm (12 in.) beyond the defective portion. The second and each succeeding ply of the patch shall extend at least 75 mm (3 in.) beyond the preceding ply.

The work shall be regulated so that at the end of the day all fabric that has been laid shall have received the final coat of bitumen, except that the fabric for making the lap shall not be mopped with bitumen until the joint is to be

completed. With the approval of the Engineer, spraying will be permitted in lieu of mopping.

(b) Butyl Rubber Membrane. Butyl rubber membrane sheets shall be laid and secured in a hot mopping of bitumen applied over the primed surfaces. When the surface has been primed using RC-70, the mopping shall be with asphalt: AWP. An adhesive, compatible to the membrane and other materials, may be used in lieu of the hot mopping of bitumen, at the option of the Contractor. If adhesive is used, it shall be applied to the areas to be waterproofed in a thin layer with a squeegee at a rate of 0.4 L/sq m (1 gal. per 100 sq. ft).

Membrane sheets shall first be positioned and drawn tight without stretching. Half of the membrane sheet shall then be uniformly rolled up in a direction away from the starting edge or subsequent splice. The bitumen or adhesive shall now be applied to the exposed area. If adhesive is used, it shall be allowed to dry so as not to stick to a dry finger touch. The membrane shall then be unrolled and pressed firmly and uniformly in place, using care to avoid trapping air. The same procedure shall be used for the remaining half of the membrane sheet. Wrinkles and buckles shall be avoided. Each succeeding sheet shall be positioned to fit the previously installed sheet and spliced.

Splices shall be of tongue-and-groove or lap type. All seam, lap and splice areas shall be cleaned with heptane, hexane, toluene, trichlorethlene or white gasoline, using a clean cloth, mop or similar synthetic cleaning device. Rubber cement shall be spread continuously on seam, lap and splice areas at a uniform rate of not less than 0.8 L/sq m (2 gal/100 sq ft). After the rubber cement is allowed to dry until it will not stick to a dry finger touch, butyl gum tape shall be applied to the cemented area of membrane. The tape shall be extended at least 3 mm (1/8 in.) beyond edges of splice and lap areas. The tape shall be rolled or pressed firmly into place so full contact is obtained. Bridging and wrinkles shall be avoided. Corner splices shall be reinforced with two continuous layers of rubber membrane over one layer of butyl tape.

All projecting pipe, conduits and sleeves passing through butyl rubber membrane waterproofing shall be flashed with prefabricated or field-fabricated boots or fitted coverings, as necessary to provide watertight construction. Butyl gum tape shall be used between layers of rubber membrane.

Any holes in the membrane sheeting shall be patched with a minimum overlap of 100 mm (4 in.) and according to the manufacturer's instructions. During construction, care shall be exercised to prevent damage to the membrane by workers or equipment.

580.05 Protective Cover. The protective cover shall be placed over the membrane as soon as practicable after the membrane has been laid. Dirt and other foreign material shall be removed from the surface of the membrane before the protective cover is placed.

At expansion joints of decks protected with butyl rubber membrane, a strip of anti-bonding paper 450 mm (18 in.) wide shall be laid above and below the membrane before the protective cover is applied.

One of the following methods of protection shall be used:

(a) A layer of asphalt plank not less than 30 mm (1 1/4 in.) thick laid in a mopping of asphalt with all joints filled with asphalt.

(b) A layer or layers of asphaltic panels not less than 20 mm (3/4 in.) in total thickness.

For bituminous membrane, the asphalt plank protection shall be laid in hot Asphalt: AWP. The asphalt shall be applied at the rate of not less than 2 L/m^2 (5 gal. per 100 sq. ft) of surface. As successive planks are laid, the edges and ends of adjacent planks already laid shall be coated heavily with hot asphalt. The planks shall be laid tight against those previously laid so that the asphalt will completely fill the joints and be squeezed out at the top. After all planks are laid, any joints not completely filled shall be filled with hot asphalt. The ends of adjacent planks shall be staggered.

For butyl rubber membrane, the asphalt plank shall be laid in a coating of bonding adhesive. The bonding adhesive shall be the same as that used for securing the membrane to the deck. The adhesive shall be applied at a rate of not less than 0.4 L/sq m (1 gal. per 100 sq. ft). Voids between the joints shall be filled with a compatible material.

Asphaltic panels are available in various thicknesses. To obtain the thickness of 20 mm (3/4 in.) required, the recommended application is in two layers with the joints staggered. The panels shall be laid tight jointed with an approved adhesive. For bituminous membrane, the asphaltic panels shall be laid in hot Asphalt: AWP and for butyl rubber membrane, the panels shall be laid in a coating of bonding adhesive. The application rate shall be the same as previously specified for asphalt planks. Any voids between the panels shall be filled with a material compatible to both the membrane and the panel.

When asphaltic panels are used as a protective cover, a 50 mm (2 in.) layer of fine aggregate shall be placed over the panels as a cushion prior to placement of ballast. The cost of this cushion shall be included in the bid price for membrane waterproofing.

580.06 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. The membrane waterproofing will be measured for payment in place, and the area computed in square meters (square feet). The area for measurement will include only the surface of the membrane waterproofing covered with a protective cover.

580.07 Basis of Payment. This work will be paid for at the contract unit price per square meter (square foot) for MEMBRANE WATERPROOFING.

SECTION 581. WATERPROOFING MEMBRANE SYSTEM

581.01 Description. This work shall consist of furnishing and placing a waterproofing membrane system over a properly prepared concrete bridge deck prior to placing of the bituminous concrete surface course.

581.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Water	1002
(b) Waterproofing Membrane System	1061

The waterproofing membrane system shall consist of a penetrating primer, a built-up coal tar pitch emulsion membrane with two plies of coated glass fabric, and a 13 mm (1/2 in.) thick asphalt sand seal protection layer.

CONSTRUCTION REQUIREMENTS

581.03 General. All methods employed in performing the work and all equipment, tools and machinery used for handling materials and executing any part of the work shall be subject to approval of the Engineer before the work is started, and whenever found unsatisfactory, shall be changed or improved as required. All equipment, tools, machinery and containers used shall be kept clean and maintained in a satisfactory condition.

581.04 Preparation of Concrete Deck. All surfaces which are to be covered shall be thoroughly cleaned by the use of air jets, water jets, mechanical sweeper, hand brooms, or other approved methods, or as required by the Engineer until the surface is free of all sand, clay, dust, salt deposits, and all loose or foreign matter. Any accumulations of oil or grease shall be scraped off the surface of the roadway after which those areas shall be cleaned with a strong caustic solution, the residue of which shall be thoroughly flushed away with clean water before application of the primer.

All cleaned areas shall be primed without delay as soon as they are dry. All dust and dirt shall be blown off with air jets immediately preceding application of primer. Any unusually sharp concrete edges on the deck surface which could puncture the membrane shall be corrected in a manner satisfactory to the Engineer prior to application of the primer. Exposed aggregate or rough spots shall be smoothed.

A 13 mm to 20 mm (1/2 to 3/4 in.) fillet of concrete or epoxy grout shall be placed in the cove area between curb, parapet, median and expansion dam faces and the deck surface to prevent a void area where the membrane turns up the vertical face.

Concrete surfaces, structural steel, railing, passing vehicles, etc. shall be protected to prevent their being defaced by primer or other materials being used.

Should defacement occur, the Contractor shall clean surfaces on the structure to the satisfaction of the Engineer and be solely responsible and liable for damage to passing vehicles. From the time the bridge deck is cleaned and prepared for the prime coat until the bituminous concrete is spread and compacted, the only traffic permitted on the area being treated shall be the necessary men and equipment to perform the work required.

581.05 Weather and Moisture Limitations. Weather and Moisture Limitations. Work shall not be done during wet weather conditions, nor when the deck and ambient air temperatures are below 7 ºC (45 ºF). The deck shall be surface-dry at the time of the application of the primer. The membrane shall not be placed until at least 28 days after deck-concrete placement on new structures unless otherwise directed. On existing structures where the normal traffic flow is interrupted by the project work, as much drying time after the curing period shall be allowed as is feasible before membrane placement.

581.06 Application of Membrane System. Pressure distributors used for the application of the tar emulsion shall be self-propelled, equipped with pneumatic tires, and capable of applying 0.4 to 0.5 L/sq m (0.08 to 0.10 gal. per sq. yd.) of tar emulsion over the required width of application. Distributors shall be equipped with removable manhole covers, tachometers, pressure gauges and volume measuring devices.

Mixing and agitating equipment furnished shall be either a portable power mixer or a tank-type power mixer. A portable mixer for use in drums shall have sufficient power and propeller blades shaped to thoroughly mix and pull the material upward from the bottom of the drum. Mixing in tanks may be done in round bottom tanks equipped with a power driven mixer of sufficient capacity to maintain the emulsion in suspension.

The primer and full membrane shall extend up the curb faces and other vertical barriers to at least the elevation of the top of the surfacing. The lips of drain openings and edges of open joints, deck slab and other openings at deck level shall be completely sealed by extending the full waterproofing course over the lip or edge.

The penetrating primer shall be applied by spraying, preferably with high pressure hydraulic equipment using hand-held spray bars that permit close control of the quantity applied. Applied at the rate of approximately 0.05 L/m^2 (0.01 gal./sq. yd.), the quantity shall be controlled to produce a "brown coat" filling all pores and depressions but devoid of lakes or pools showing a solid film when dried out. The purpose of the primer is to neutralize the concrete surface and not to produce a membrane film by itself.

Primer shall not be diluted unless ordered by the Engineer. A distributor truck shall not be used to apply the primer unless its performance has been demonstrated and its use approved by the Engineer. Surfaces shall be dry when primer is applied, and the weather and atmospheric conditions favorable for a drying period of at least four hours. Care shall be taken that the primer does not flow onto nor is applied over bituminous or mastic materials.

Coal Tar Pitch emulsion shall not be applied until the primer has cured for 24 hours or until all solvents that may cause bleeding of the emulsion have evaporated.

The coal tar pitch emulsion coatings shall not be applied when the weather is foggy or when rain threatens, or when the atmospheric or pavement temperature is below 7 ºC (45 ºF).

Due to the settling that may take place in transit, the emulsion shall be thoroughly agitated by power mixers so that a homogeneous consistency is assured for proper and uniform application.

A total of four applications of emulsion shall be applied to the deck, the fourth coat being in the form of a slurry. The slurry shall be applied at the rate of 1.4 L/sq m (0.30 gal. per sq. yd.) in order to obtain 0.5 to 0.6 L (0.13 to 0.15 gal.) of undiluted coal tar emulsion per square meter (square yard). The first three coats of undiluted coal tar emulsion shall be applied at the rate of 0.4 to 0.5 L/sq m (0.08 to 0.10 gal. per sq. yd.). Two layers of fiberglass fabric shall be placed parallel to the length of the bridge. The necessary time shall be allowed between coats for proper setting. After the roadway surface has been properly primed and approved by the Engineer, the coal tar pitch emulsion shall be applied according to one of the two following methods:

(a) Hand Method - The emulsion shall be applied in four coats in the amounts per square meter (square yard) as required. The undiluted material shall be poured in strips on the pavement and spread with a squeegee or brush, smoothing out with a brush. This procedure shall be continued until the entire area is covered. Application can also be made by means of a heavy spray gun when approved by the Engineer. The first coat shall be allowed to dry or cure sufficiently to prevent pickup before the second coat is applied. When spreading the second coat, it shall be spread crosswise to the placing of the first coat when practicable.

(b) Distributor or Applicator - When applied by distributor or approved type of applicator, the emulsion shall be applied uniformly to the surface of the pavement at the prescribed pressures and in the amount per square meter (square yard) as stated. The emulsion shall be thoroughly mixed before use. When necessary to dilute the emulsion in order to aid proper application, the emulsion may be diluted with a maximum of ten percent by volume of clean fresh water as directed by the Engineer.

In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed so that water will run over and not against the laps.

One width of the fiberglass fabric shall be laid loosely into the second coat of emulsion while the film is still wet. The fabric shall be brushed into the emulsion thereby eliminating all wrinkles and blisters, but without stretching the fabric tight. The adjoining widths of fabric shall be installed in the same fashion, side lapping the former by 75 mm (3 in.). All end laps shall be at least 300 mm (12 in.). The upper layer of fabric shall be applied in the same manner, but the laps shall extend over the lower laps by at least 150 mm (6 in.).

The fourth coat shall be a slurry top coat. The emulsion and aggregate shall be blended and premixed to produce a slurry top coat. The coal tar emulsion may be diluted up to a ratio by volume of 0.1 parts water to one part coal tar pitch, emulsion

to facilitate the mixing and spreading of the slurry. The slurry shall contain a nominal 0.5 kg (4 lb) of fine aggregate per liter (gallon) of coal tar pitch emulsion.

Before application, the materials shall be proportioned accurately and mixed by suitable mixing equipment. Mixing machines for preparing the slurry may be mortar mixers, concrete mixers, or any type approved by the Engineer capable of producing a uniform mixture of emulsion and aggregate. The emulsion and the water shall be first charged into the mixer and blended into desired consistency, then the aggregate shall be added at a slow and uniform rate while the mixing is continued until the batch aggregate is incorporated. After all the components are in the mixer, the mixing shall continue for minimum of five minutes or as long as may be necessary to produce a smooth, free flowing, homogeneous mixture of a uniform consistency. Mixing shall be continuous from the time the bitumen is placed into the mixer until the slurry is poured into the spreading equipment.

During the entire mixing process, there shall be no breaking, segregating or hardening of the emulsion, nor balling, lumping or swelling of the aggregate. After the required mixing period, the slurry shall be spread over the designated area while the slurry is of the proper consistency. The slurry shall be uniformly spread over the last layer of the fiberglass fabric at the rate of 0.5 to 0.6 L (0.13 to 0.15 gal.) of undiluted coal tar emulsion per square meter (square yard) of surface. The slurry shall be applied at the rate of 1.3 to 1.4 L/sq m (0.28 to 0.30 gal. per sq. yd.) in order to obtain 0.5 to 0.6 L (0.13 to 0.15 gal.) of undiluted coal tar emulsion per square meter (square yard).

The application of the slurry shall be either by hand methods using rubber squeegees for spreading or by any other suitable mechanical method approved by the Engineer. The slurry shall be applied at a uniform rate as specified.

A suitable spray type applicator or distributor approved by the Engineer may be used for applying the slurry. Such equipment shall be equipped with an agitator to keep the slurry uniformly mixed before and during application and so designed to uniformly spread the slurry on the roadway at the specified rate of application.

At all times, particular care shall be taken to protect the membrane from damage. Any damage which may occur shall be repaired by patching in a manner satisfactory to the Engineer. The complete membrane shall be allowed to cure for at least 24 hours before placement of the protection layer.

581.07 Protection Layer. The fine aggregate and asphalt cement shall be combined in such proportions that the composition by weight of the finished mixture shall be as directed by the Engineer but within the following range limits:

Fine Aggregate	90.0 to 93.0%
Bitumen	7.0 to 10.0%

The hot-mix plant used for the manufacture of the protection course material shall be capable of producing completely coated uniform mixtures within the tolerances set forth and at a uniform workable temperature as specified by the Engineer, but not to exceed 175 ºC (350 ºF) for the mixture when leaving the plant.

The exact proportions, within the limits specified, shall be regulated so as to produce a satisfactory mixture with all particles coated with asphalt cement. The fine aggregate shall be mixed dry for not less than 15 seconds. The asphalt cement shall then be added in an evenly spread sheet over the full length of the mixer box. The mixing shall be continued for a period of not less than 30 seconds and at least until the aggregate is completely coated with bitumen.

The asphalt sand seal protection layer shall be placed and compacted according to the requirements of Section 406 except that the material shall not be mixed or placed when the atmospheric temperature is below 10 ºC (50 ºF). The temperature of the mix shall not be less than 144 ºC (290 ºF) at time of placement. The mix shall be placed and compacted so as to provide a protection layer of approximately 15 mm (1/2 in.) in thickness.

581.08 Sequence of Construction Operations. The sequence of construction operations for the waterproofing membrane systems shall be as follows:

(a) Penetrating Primer 0.05 L/sq m (0.01 gal./sq. yd.) [Cure 24 Hours]

(b) Coal Tar Emulsion 0.4 to 0.5 L/sq m (0.08 to 0.10 gal./sq. yd.) [Cure 4 Hrs.]

(c) Coal Tar Emulsion 0.4 to 0.5 L/sq m (0.08 to 0.10 gal./sq. yd.) & Fiberglass Fabric 55 g/m^2 (1.65 oz./sq. yd.) [Cure 4 Hrs.]

(d) Coal Tar Emulsion 0.4 to 0.5 L/sq m (0.08 to 0.10 gal./sq. yd.) & Fiberglass Fabric 55 g/m^2 (1.65 oz./sq. yd.) [Cure 4 Hrs.]

(e) Coal Tar Emulsion Slurry 1.4 L/sq m (0.3 gal./sq. yd.) incl. (Cure 24 Hrs.)

(f) Asphalt Sand Seal Protection Layer 13 mm (1/2 in.) thick

581.09 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. The waterproofing membrane system, complete in place and accepted, will be measured for payment and the area computed in square meters (square yards) of bridge deck surface covered. No measurement or allowance will be made for laps, material used for extending up curb faces or other vertical barriers, material used for extensions over lips or edges, or for repairs.

581.10 Basis of Payment. This work will be paid for at the contract unit price per square meter (square yard) for WATERPROOFING MEMBRANE SYSTEM.

SECTION 582. BITUMINOUS CONCRETE SURFACING ON BRIDGE DECKS

582.01 Description. This work shall consist of constructing a bituminous concrete surface course on a prepared bridge deck.

582.02 Compaction Equipment. The breakdown rolling shall be accomplished with a tandem roller having a unit compression on the drive wheels of not less than 44 nor more than 70 N/mm (250 nor more than 400 lb/in.) of roller width. Vibratory rollers will not be permitted on bridge decks.

CONSTRUCTION REQUIREMENTS

582.03 General. The work shall be performed, measured and paid for according to the requirements of Section 406, except as specified for obtaining the density.

582.04 Target Density. A target density will be established from tests conducted on a calibration strip consisting of 30 m (100 ft) of bituminous concrete surface course mixture placement on the bridge deck. The mixture used shall conform to the requirements of the approved job-mix formula for the project.

A target count rate which represents maximum compactive effort will be determined with nuclear testing equipment within calibration strip.

Compaction of the strip with the breakdown roller shall commence immediately after the surface course is placed and shall be continuous and uniform over the entire area. All rolling operations must be completed before the temperature of the mixture drops below 90 ºC (190 ºF). At a minimum of two random locations within the calibration strip, a growth curve consisting of a plot of counts per minute vs. number of passes with a breakdown roller will be developed.

The growth curve at each random location will be established by using a nuclear gauge using a fast count or with a nuclear gauge using a 30-second timing cycle in the backscatter position. Tests will be made after each pass until the lowest count either raises or remains the same. At this time, mineral filler will be spread and a 4 minute (calibration) count will be taken in the backscatter position to establish the relative target density.

The established average target density shall apply throughout the project unless there are changes in materials in the mix and/or an appreciable change in the job-mix formula. The Engineer may require a new average target density to be established if there is reason to believe that the mixture being placed is not the same as the mixture used to determine the target density.

Unless otherwise provided, the cost of constructing the calibration strip will be considered included in to the cost of the mixture for which a strip is required.

582.05 Acceptance Tests. Acceptance tests will be performed once the average target density has been established. At least one acceptance test will be taken for each 60 m (200 ft) or portion thereof of bridge deck per paver pass.

Acceptance tests on material placed in a single day shall average 98 percent of the established average target density with no one test being below 95 nor more than 103 percent of the established target density. If the above requirements for average or individual density tests cannot be obtained, placement of additional material will be discontinued until the cause of the failure is investigated and corrected.

Acceptance tests will be performed with the same nuclear equipment used to establish the average target density. Acceptance tests will be for one-minute duration and the area to be tested shall be prepared with mineral filler prior to testing.

SECTION 583. PORTLAND CEMENT MORTAR FAIRING COURSE

583.01 Description. This work shall consist of placing portland cement mortar along precast, prestressed concrete bridge deck beams as required for fairing out any unevenness between adjacent deck beams prior to placing of waterproofing membrane and surfacing.

583.02 Materials. Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

Item	Article/Section
(a) Portland Cement	1001
(b) Fine Aggregate	1003.02
(c) Water	1002

CONSTRUCTION REQUIREMENTS

583.03 General. The mixture for portland cement mortar shall consist of three parts sand to one part portland cement by volume. The amount of water shall be no more than that necessary to produce a workable, plastic mortar.

Prior to placement of the mortar fairing course, all areas where unevenness occurs between the deck beams shall be prepared and coated with a grout according to Article 503.09 (b) (1).

The mortar shall be placed to the thickness necessary to eliminate unevenness between the beams. It shall be placed to form a smooth even surface from the higher beam edges to the lower surface. The mortar finished surface shall slope not less than 1:3 (V:H) and shall be feathered smoothly into the deck beam surfaces. The finish shall be free of depressions or sharp edges.

The mortar shall be cured for a period of not less than three days by the wetted burlap method according to Article 1020.13(a)(3). Curing shall commence as soon as practicable after mortar placement.

583.04 Method of Measurement. Portland cement mortar fairing course will be measured for payment in meters (feet) along the beam edges.

583.05 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for PORTLAND CEMENT MORTAR FAIRING COURSE.

SECTION 584. EPOXY GROUTING OF ANCHOR RODS AND BARS

584.01 Description. This work shall consist of drilling and epoxy grouting anchor rods and bars into hardened concrete when specified or when approved by the Engineer.

584.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Epoxy Grout	1025.04

CONSTRUCTION REQUIREMENTS

584.03 General. Holes shall be drilled in the concrete to 6 mm (1/4 in.) larger in diameter than the diameter of the anchor rods or bars and to the depth shown on the plans. A template or other approved method shall be used to assure accurate location of the drilled holes. All holes shall be blown free of concrete dust and chips and shall be absolutely dry prior to placing the epoxy grout.

Prior to inserting the anchor rod or bar into the hole, the hole shall be filled approximately 1/3 full of the mixed epoxy grout. The anchor rod or bar shall be inserted into the partially filled hole and moved up and down several times to insure total contact of the grout with concrete as well as the rod or bar. Additional grout shall be extruded to proper concrete level and finished as necessary. The anchor rod or bar shall be aligned to maintain a perpendicular plane. No load shall be applied to the anchors until the grout has cured for at least 24 hours.

584.04 Basis of Payment. The drilling of the holes, furnishing of the epoxy grout and setting of the anchor rods or bars in the epoxy grout will not be measured or paid for separately, but shall be considered as included in the unit price bid for the item of construction involved.

SECTION 585. EPOXY MORTAR REPAIR

585.01 Description. This work shall consist of furnishing all materials and labor required to remove deteriorated concrete and replace it with an epoxy mortar at those locations shown on the plans or designated by the Engineer.

585.02 Materials. Materials shall be according to the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Epoxy Mortar	1025.02

CONSTRUCTION REQUIREMENTS

585.03 General. The areas to be patched shall have all loose, unsound concrete removed and then cleaned by sandblasting, vacuumed and/or blown clean with oil-free compressed air. The sound concrete remaining shall then be scrubbed with an epoxy-resin prime just prior to the placement of the epoxy mortar.

The epoxy mortar shall be mixed and placed according to the manufacturer's printed instructions. Such instructions shall be supplied to the Contractor by the supplier of the epoxy system.

The mortar shall be placed and finished to the contours of the member as originally constructed.

585.04 Method of Measurement. Epoxy mortar repair will be measured for payment in place and the volume computed in liters (cubic feet).

585.05 Basis of Payment. This work will be paid for at the contract unit price per liter (cubic foot) for EPOXY MORTAR REPAIR.

SECTION 586. SAND BACKFILL FOR VAULTED ABUTMENTS

586.01 Description. This work shall consist of furnishing, transporting and placing a sand backfill behind vaulted abutment mainwalls to serve as a form for the placement of the concrete approach slab.

586.02 Materials. Materials shall conform to the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Fine Aggregate (Note 1.)	1003.01

Note 1. The material for backfilling shall be a bank-run or stockpiled sand.

CONSTRUCTION REQUIREMENTS

586.03 General. The wedge behind the abutments shall be backfilled with the sand material to the required elevation of the bottom of the approach span slabs. The backfill shall be placed in convenient lifts for the full width between the abutment sidewall. Mechanical compaction will not be required. Backfilling shall not be started until test specimens show that the concrete in the abutment has attained a flexural strength of 4,500 kPa (650 psi) but in no case until at least seven days have elapsed after the placing of the concrete. In the absence of tests to determine the flexural strength, the sand backfill shall not be placed until at least 14 days have elapsed after the placing of the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 7 ºC (45 ºF).

The sand backfill shall be brought to the finished grade of the bottom of the abutment approach slab to serve as a base for placement of the slab. The Contractor, subject to approval of the Engineer, may prepare the top surface of the fill

to receive the concrete as he/she deems necessary for satisfactory placement, except no additional compensation will be allowed for the method used.

586.04 Method of Measurement.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Sand backfill will be measured for payment in place, and the volume computed in cubic meters (cubic yards). The volume shall be determined by measuring the wedge areas above the embankment slope, behind the abutment mainwalls, and for the full width between sidewalls.

586.05 Basis of Payment. This work will be paid for at the contract unit price per cubic meter (cubic yard) for SAND BACKFILL.

SECTION 587. BRIDGE SEAT SEALER

587.01 Description. This work shall consist of furnishing the required materials, cleaning bridge seats, and applying a sealer to the bridge seats of piers and/or abutments as described and all incidental and collateral work as required to perform the work as directed by the Engineer.

587.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Bridge Seat Sealer	1026

CONSTRUCTION REQUIREMENTS

587.03 General. Before the sealer is applied, the bridge seats shall be cleaned with high pressure air blast or wire brushes to remove all oil, grime, and loose particles to clean, bare concrete. Surfaces that will not respond to cleaning by air blast or wire brushes shall, if required by the Engineer, be cleaned by sandblasting.

Extreme care shall be taken to prevent the sealer from flowing over the edges and onto the sides of the abutments or piers.

The sealer shall be applied according to the manufacturers' instructions.

587.04 Basis of Payment. This work will be paid for at the contract unit price per square meter (square foot) for BRIDGE SEAT SEALER.

SECTION 588. CONCRETE JOINT SEALER

588.01 Description. This work shall consist of furnishing all the required materials, and the placement of a concrete joint sealer of a two-component, cold-applied, elastomeric, polymer type and a rod of polychloroprene, rubber or any other approved material, to seal the horizontal joint in the bridge roadway slab.

588.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Concrete Joint Sealer	1058

CONSTRUCTION REQUIREMENTS

588.03 General. The faces of all joints to be sealed shall be free of all foreign matter, curing compound, oils, grease, dirt, free water, and laitance. Concrete joints to be sealed shall be free of cracked or spalled areas. Any cracked areas shall be chipped back to sound concrete before placing joint sealer.

The concrete joint sealant shall be applied only when the ambient temperature is 20 ºC (68 ºF) and rising.

A continuous length of rod of the size designated on the plans, shall be placed in the joint opening at the depth below the finished surface of the joint shown on the plans. The surface of the rod shall be wiped clean with solvent (toluene or xylol) before installation.

All sealing compound shall be placed with an applicator recommended by the manufacturer, and the mixing and placing instructions of the manufacturer shall be adhered to. A copy of these directions and the specifications for the applicator to be used shall be filed with the Bureau of Materials and Physical Research.

No sealing compound shall be placed in a joint on any material (joint filler or expansion board) containing any bituminous material until a separating barrier of foil or other suitable material has been placed on top of bituminous material in such a manner so that the sealing compound cannot contact the bituminous material. No material that will allow bitumen to soak through may be used. When it is deemed necessary to prevent bonding of the sealing compound to a joint surface, the Engineer may require the Contractor to place, at no extra cost, paper, plastic, or foil barriers over the joint surface before applying the sealing compound.

The joint must be covered with a masking tape before the application of the protective coat on the bridge deck to prevent the spray from filming the vertical faces.

All bridge joints shall be filled to 6 mm (1/4 in.) below the finished surface of the joint. This is to be interpreted to mean that the surface of the sealant shall be level and the point of its contact with the sidewalls of the joint shall be 6 mm (1/4 in.) below the finished surface of the joint.

Any sealing compound that is not bonded to the joint wall or face twenty-four hours after placing shall be removed and the joint shall be cleaned and resealed at the Contractor's expense.

588.04 Basis of Payment. Furnishing and placing the closure rod and polymer compound joint sealer, will not be paid for as a separate item, but shall be considered as included in the unit price bid for the major item of construction involved, and no additional compensation will be allowed.

SECTION 589. ELASTIC JOINT SEALER

589.01 Description. This work shall consist of furnishing and placing an elastic sealer in joints of bituminous concrete surface course on bridge decks according to the details shown on the plans and as directed by the Engineer.

589.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Elastic Joint Sealer	1059

CONSTRUCTION REQUIREMENTS

589.03 General. Prior to sealing, the joint shall be sawed to form a reservoir for the sealing material. The sawed joint shall be 5 mm (1/4 in.) wide and 20 mm (3/4 in.) deep. Immediately prior to pouring the elastic sealer, the joint shall be cleaned with compressed air and shall be free of foreign and loose material and in a dry condition. The joint shall not be poured when the temperature is below 4 ºC (40 ºF) or when the weather is foggy or rainy.

The equipment required for this work shall be approved by the Engineer before the work will be permitted to start. The heating apparatus and equipment for applying the sealing material shall meet the recommendations of the manufacturer supplying the sealing material, and shall be such that the joint will be completely filled from bottom to top to the satisfaction of the Engineer.

Sufficient compound shall be placed in the joints so that the top of the seal is flush with the top surface of the wearing course.

589.04 Basis of Payment. Sawing and cleaning the joint, and furnishing and placing the sealer, will not be paid for as a separate item, but shall be considered as included in the unit price bid for the item of bituminous concrete surface course involved, and no additional compensation will be allowed.

SECTION 590. EPOXY CRACK SEALING

590.01 Description. This work shall consist of furnishing of all labor and material required to seal cracks in structural concrete with an epoxy bonding compound as shown on the plans and as directed by the Engineer.

590.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Epoxy Bonding Compound	1025.03

CONSTRUCTION REQUIREMENTS

590.03 General. The areas designated for epoxy crack seal repair shall be prepared for sealing by removing all dust, debris, or disintegrated material from the crack by the use of oil-free compressed air and/or vacuuming. Any cracks holding oil or grease must be chipped out to clean concrete.

Horizontal cracks shall be grouted by pouring mixed material into the clean, "vee'd" out cracks. Vertical cracks shall be grouted by installing suitable pipe nipples, zerk or alemite fittings, or polyethylene one-way valves every 300 to 900 mm (1 to 3 ft) as required, depending on width of crack. Surface of cracks between nipples or fittings shall be sealed with a suitable sealing compound recommended by the supplier of the bonding compound. When the sealing compound is hard, a standard caulking gun or other suitable pressure gun shall be used to pump the compound into the cracks, starting at the lowest nipples or fittings and progressing upward until all cracks are grouted. When the grout is cured, the fittings shall be removed and the surface smoothed by stoning or grinding.

590.04 Method of Measurement. Epoxy Crack Sealing will be measured in for payment in meters (feet), complete in place.

590.05 Basis of Payment. This work will be paid for at the contract unit price per meter (foot) for EPOXY CRACK SEALING.

SECTION 591. GEOCOMPOSITE WALL DRAIN

591.01 Description. This work shall consist of furnishing and installing geocomposite wall drain on the soil side of abutment walls, wing walls, retaining walls and culvert sidewalls.

591.02 Materials. Materials shall meet the requirements of the following Article of Section 1000 - Materials:

Item	Article/Section
(a) Geocomposite Wall Drain	1040.21

CONSTRUCTION REQUIREMENTS

591.03 General. Geocomposite wall drain shall be constructed in horizontal courses with the first course resting on the top of the footing. The geocomposite shall be in intimate contact with the wall and secured with concrete nails not less than 50 mm (2 in.) long with approved washers not less than 5800 sq mm (9 sq in.) in area. The spacing of the concrete nails shall be as directed by the Engineer but shall not be

more than 1 m (3 ft) apart, both horizontally and vertically. There shall be at least one horizontal row of nails in each course.

Horizontal seams shall be formed by a 100 mm (4 in.) flap of geotextile extending from the upper course and lapping over the top of the lower course or by a 300 mm (12 in.) wide continuous strip of geotextile centered over the seam and securely fastened to the upper course with continuous 75 mm (3 in.) wide plastic tape. The overlapping flap or strip shall be fastened to the lower course intermittently as directed by the Engineer, but the spacing shall not exceed 600 mm (2 ft). Vertical splices shall be formed by a 100 mm (4 in.) flap of geotextile extending from one or the other abutting pieces or by a 300 mm (12 in.) wide continuous strip of geotextile centered over the splice. Vertical splice flaps or strips shall be continuously fastened to the geocomposite with continuous applications of contact adhesive or 75 mm (3 in.) wide plastic tape.

The bottom, side and top edges of the geocomposite shall be covered with a suitable cap formed by folding a 150 mm (6 in.) flap or a 300 mm (12 in.) wide strip of geotextile over the edge and securing it in place with a continuous application of contact adhesive or 75 mm (3 in.) wide plastic tape. All seams, splices, bottom caps, top caps and end caps shall be constructed so that backfill material cannot enter the geocomposite during or after construction.

Connection to pipe outlet systems shall be as shown on the plans. Outlet fittings shall be fastened to the wall drains as directed by the manufacturer and so that backfill materials cannot enter the system during or after construction. If necessary, to facilitate the rapid and complete flow of water from the wall drain into the pipe outlet, a portion of the wall drain core equal to the cross section at the outlet shall be removed. Weep holes shall be accommodated by cutting a matching hole through the wall drain. An approved weep hole cover extending at least 100 mm (4 in.) from the edge(s) of the hole shall be securely fastened to the soil side of the wall drain by 75 mm (3 in.) wide plastic tape or contact adhesive applied continuously around its periphery.

591.04 Method of Measurement. Geocomposite wall drain will be measured for payment in place in square meters (square yards) of actual surface area covered.

591.05 Basis of Payment. This work will be paid for at the contract unit price per square meter (square yard) for GEOCOMPOSITE WALL DRAIN.

SECTION 592. BRIDGE WASHING

592.01 Description. This work consists of the removal of all accumulated foreign material from the entire bridge, including bridge deck, sidewalk, curbs, pier and abutment caps, all superstructure members, trusses, interior of truss members, flanges and webs of beams or girders, washing of expansion joints and drains, to prevent deterioration of the structure.

592.02 Equipment. Washing equipment shall consist of power brooms, air compressors, water tanks, water pumps with associated delivery hardware, and hand tools, to properly flush, clean, and remove all foreign material from the bridge structure. Other types of washing equipment may be used, subject to approval of the

Engineer. Water pressure shall be sufficient to remove the accumulated material without damaging paint coverage of the structural steel.

Other equipment may be necessary to gain access to areas designated for washing. It will be the Contractor's responsibility to determine and utilize whatever method and equipment best suits his/her operation to successfully wash the structures. This equipment shall be available to the inspector until final acceptance of the work.

CONSTRUCTION REQUIREMENTS

592.03 General. All accumulated foreign material shall be removed from the bridge. Special care shall be taken on connected parts, members below open joints and difficult to reach areas to remove all foreign material.

All deck drains shall be flushed with water under pressure. Blockages in the deck drains shall be removed so that they will drain properly. The drain system may have to be taken apart to remove large blockages. Should they be taken apart, they shall be returned to their original configuration immediately after washing. Foreign material in the scuppers at the drains shall be either removed externally or flushed down the drain system. The area beneath all expansion devices shall be thoroughly flushed and washed with water under pressure. These areas include drain troughs beneath the expansion device and pier tops immediately adjacent to the expansion device. All abutment and bridge seats shall have foreign material removed by compressed air, water under pressure, or hand sweeping. All structural steel and bearings shall be washed with water under pressure. All foreign debris shall be removed from truss members. All foreign material accumulated in the interior of members shall be removed. Areas which have been washed shall be free of all accumulate sand, gravel, dirt, bird nests and excrete, and other foreign materials. Free standing water shall be removed upon completion of washing.

The Contractor shall provide adequate protection against worker inhalation of dust from his/her washing operations.

The Contractor shall exercise due caution while washing those portions of the structures that are adjacent to or above parking lots, buildings, sidewalks, roadways, and railroad tracks. Dirt and debris deposited on adjacent property or redeposited on the bridge shall be removed to the satisfaction of the Engineer at the Contractor's expense.

The Contractor shall obtain his/her own source of water. The water shall be according to Section 1002. Any expense involved in securing the proper water shall be borne by the Contractor.

592.04 Traffic Control. The road shall be kept open to traffic according to the requirements of Article 701.05(d)(4).

592.05 Method of Measurement. Bridge washing will be measured for payment in units of each at the locations specified.

592.06 Basis of Payment. This work will be paid for at the contract unit price each for BRIDGE WASHING at the location specified.